4 Conclusions

Several initial conclusions may be made based on an initial analysis of the data collected at the regional exploration workshops. This section compares the workshop data to the national vision contained within the *Frontier Report*, discusses the probable impact of these data on capital assets such as research vessels and supporting equipment, and presents related issues arising from the workshop proceedings.

4.1 Synergy with *Frontier Report*

The road map provided by the *Frontier Report* presents four national exploration objectives[7], each with a subset of elements describing the specific challenges within the stated objectives. As detailed in Table 2-2, these objectives and their elements provided the foundation for the workshop process and offered general guidance to workshop participants on areas of exploration emphasis. Since the two exploration objectives related to technology development and reaching out in new ways to stakeholders were presented as crosscutting themes during the workshops, each of the exploration needs categories from the workshops listed in Section 3.1 include components from both of these objectives. The emphasis of elements comprised within the two objectives related to mapping and dynamics are more specific in their application to ocean exploration. The relationship between these elements and the exploration needs categories identified by the workshop participants is provided in Table 4-1. Several conclusions may be reached using this table in conjunction with detailed information on the exploration needs categories presented in Section 3.

- The national emphasis on biological, geological, chemical, and physical interactions and exploration of the connections between living and nonliving systems is nearly ubiquitous among the categories of exploration needs. This result is consistent with the desirable characteristic stated in the *Frontier Report* that each facet of exploration should be multidisciplinary by necessity.[8] It also supports a commonly held view that involvement of subject matter experts across multiple scientific disciplines is fundamental to successful ocean exploration. Their involvement is necessary to ensure new, discipline-specific discoveries are recognized from within diverse ocean exploration data.

Table 4-1. Relationship Between Elements of Selected Frontier Report Objectives and Workshop Exploration Needs Categories

Workshop Exploration Needs Category	Elements of Selected *Frontier Report* Objectives								
	Archeological Sites	Resources	New Species	Ecosystems	Ocean's Interior	Ocean Floor	Ocean Properties	Sea Surface	Bio/Geo/Chem & Physical Interaction
Archeology	X					X			
Artificial Habitats	X			X					X
Benthic Environment		X	X	X		X			X
Boundary Fluxes - Air/Sea					X		X	X	X
Boundary Fluxes – Basins					X	X	X		X
Corals - Deep Water		X	X	X					X
Corals - Shallow Water		X	X	X					X
Currents & Water Masses					X		X	X	X
Ecosystem – General		X	X	X					X
Ecosystem - Abrupt Topography		X	X	X		X			X
Ecosystem - Banks & Basins		X	X	X		X			X
Ecosystem - Extreme Environments – Sea Ice		X	X	X					X
Ecosystem - Extreme Environments - Vents, Seeps & Volcanoes		X	X	X		X			X
Ecosystem – Caves		X	X	X					X
Ecosystem – Lakes		X	X	X					X
Ecosystem - Shoreline to Ledges		X	X	X		X			X
Ecosystem – Slopes		X	X	X		X			X
Episodic Events					X		X	X	X
Geology & Geomorphology		X		X	X	X		X	X
High Resolution Bathymetry					X	X			
Human Impacts		X					X	X	X
Marine Conservation	X	X	X	X		X			X
Marine Microorganisms		X	X	X				X	X
Marine Organisms		X	X	X					X
Ocean Resources – Bioprospecting		X	X	X		X			X
Ocean Resources - Energy & Minerals		X			X	X			X
Pelagic Environment		X	X	X	X				X
Sound in the Ocean		X		X	X	X	X		

- The *Frontier Report* emphasizes mapping as a means of characterizing ocean areas not previously observed and conveying the results of discovery. While there is a specific needs category for high-resolution bathymetry, the mapping needs identified during the workshops are encompassed within almost every single needs category. The mapping aspect of ocean exploration is viewed as a fundamental and mandatory component of the process of documenting discoveries.
- The importance in the *Frontier Report* on the search for knowledge related to new communities of organisms in ecosystems that display novel relationships with their environments and provide sources of new species and oceanographic resources was a major interest of workshop participants. The categories related to ecosystems have the greatest impact on requirements—both in volume and technology development—related to the mapping of previously unobserved regions.
- The element associated with the identity, location, and abundance of living and nonliving resources was a priority among the ocean explorers represented at the workshops. Although the *Frontier Report* identifies the U.S. EEZ and continental margins as geographic foci for application of this element, workshop participants were not constrained by this paradigm and identified many regions of interest outside these areas.
- Elements in the *Frontier Report* related to general physical oceanography and dynamic features of the physical ocean—particularly those related to surface observations—were not emphasized by workshop participants to the same level as other exploration needs. One possible explanation is the extensive ongoing investment in research activities related to global climate change and the hydrological cycle, activities that are rooted in hypothesis-based research and provide a steady stream of serendipitous discoveries. Another explanation is the perception among participants that remote sensing of the sea surface was not a goal unto itself but represented a potential data source that could be combined with a multidisciplinary mix of related ocean exploration data. It is likely that there are simply fewer opportunities for new discoveries where existing operational sensors provide routine observations, de-emphasizing the associated need for attention and investment by the OE program.
- Although the needs related to marine archeology and the preservation of America's maritime heritage were neatly confined to specific needs categories, this *Frontier Report* element was a consistently recurring need at each of the regional workshops.
- While spatial and temporal variability of the ocean and its inhabitants are both addressed in the *Frontier Report*, the workshop results accentuate spatially related exploration needs over time variant needs. Given the importance of mapping—an inherently spatial endeavor—for documenting the outcome of exploration activities, these results are not unexpected. Also, one could argue that subsequent "visits" to an area of interest to establish a temporal record of variability, following its initial revelation through exploration, would include a cadre of scientists armed with hypotheses for explaining anticipated changes and could focus on related scientific research rather than exploration.

In addition to conclusions drawn from references to Table 4-1, several other relationships between the vision contained within the *Frontier Report* and the results of the regional workshops are evident upon review of the data and are listed following this paragraph. One area that was not emphasized by workshop participants was the structure of a national exploration program and related programmatic guidance. There was an assumption among the participants that NOAA and OE would retain its current national leadership role in ocean exploration and would facilitate execution of the OE program in partnership with an appropriate suite of public and private stakeholders. Several participants requested a more formal definition of the scope of the OE program and criteria for the selection and peer review of projects so that they might tailor their proposals accordingly.

- Items within the *Frontier Report* objectives that were emphasized across all regional workshops include the need for state-of-the-art technology in supporting tools, coordinated education and outreach as a mandatory component of all exploration activities, a data management capability for exploration data, and creative collaboration with a broad population of exploration stakeholders. Workshop participants usually addressed these needs as broad, crosscutting themes critical to the success of their conceptual exploration approaches rather than unique exploration needs categories analogous to those in Table 3.1. Capital asset needs related to research vessel capacity and technologies are discussed in the following section.
- Given the fact that the eight workshops were regionally focused, associated exploration needs were naturally focused within the general geographic boundaries of each region. The national obligation to concentrate initial exploration efforts in the U.S. EEZ and continental margins claimed in the *Frontier Report* is mirrored in the workshop data. Despite the regional focus, participants were willing to nominate other geographic areas of interest, such as the Arctic and inland seas. One priority area from the *Frontier Report* that was not considered a priority by the workshop participants is the region of the Southern Ocean. Several participants explained this lack of emphasis on an assumption that exploration activities in the extreme southern hemisphere would be cost prohibitive unless the OE program had access to a dedicated exploration platform. The distribution of geographic areas of interest is illustrated in the charts contained in Section 3.4.
- Workshop participants through their nomination of potential partners from industry, government, academia, nongovernmental organizations, and the media validated the weight in the *Frontier Report* on ocean exploration partnerships. There was also recognition that NOAA and OE were strongly supportive of the spirit of this vision as evidenced by their considerable list of collaborators constructed during the initial year of the OE program. Participants validated the OE program's commitment of resources to three of the four capital investment areas listed in the *Frontier Report*:

interdisciplinary voyages of discovery in high-priority areas, data management and dissemination, and education and outreach. Participants generally agreed that the fourth investment area—platform, communication, navigation, and instrument development—would require an additional infusion of resources into the OE program in order to begin to satisfy national needs without sacrificing the viability of the program.

- Emphasis in the *Frontier Report* on realizing the potential of discoveries and protecting new discoveries was reflected in the exploration needs generated by workshop participants. While there was recognition of the commercial potential of selected discoveries and the need to protect related resources, participants did not address programmatic issues such as fast-track research initiatives and financial incentives for encouraging this commercial development. An additional interest item resulting from the workshops was the need for collaboration and incentives for industry to share unique data and information that would otherwise be unavailable to the government and the public due to their commercial value to the owner.

The combined results of the ocean exploration workshops generally reflect the four strategic objectives offered by the *Frontier Report* with emphasis on the actual conduct of exploration activities. The exploration needs and associated approaches for meeting those needs provide valuable implementation guidance for near-term execution of the OE program.

4.2 Capital Asset Needs

Impacts related to the employment of ocean exploration platforms and improved exploration technology were exposed as a byproduct of the approaches identified by workshop participants for satisfying ocean exploration needs. These impacts provided the opportunity for a qualitative assessment of the necessity for supporting platforms—particularly surface-based exploration vessels—to enable the OE program to address the needs summarized within this report.

4.2.1 Ship Capacity

An inspection of the regional workshop results in Section 3.4 reveals over 230 specific geographic interest sites and many broad-area interest regions identified by participants as desired candidates for exploration activities. While a majority of these areas are within the U.S. EEZ, there are many that are located outside these boundaries and a few at considerable distances from these waters. Section 3.4 also lists over 200 ocean exploration needs that either specifically refer to surface-based vessels as an enabling

technology (i.e., as part of a "standard package" of technologies) or imply a use of these vessels to deploy associated sensors and supporting systems. This combination of needs and locations represents many thousands of nautical miles of exploration vessels transiting and exploring these areas. Additionally, over four-dozen specific sites—and many other general regions—are identified as areas of archeological interest where an extended presence would be required to support characterization, artifact recovery, and preservation.

It is nearly impossible to quantifiably estimate the requirements for ship capacity to meet the exploration needs identified during the workshops due to the complex relationship between the geographic areas of interest and the multiple needs that apply at each location. A qualitative assessment of the requirements for ship capacity is possible using the first demonstration year of the OE program as a template for making assumptions about rates of area coverage, associated costs, leverage of partnership assets, and ship employment. During the 2001 field season, seven major expeditions employed nine ships and spent approximately 340 days at sea exploring 18 general geographic areas of interest. The activities ranged from the *Preserving the USS Monitor* archeological expedition that spanned a 140-day period at a static site and was principally supported by a Navy salvage vessel, to the *Islands in the Stream* expedition that occurred over a 110-day period and visited nine unique areas using three vessels operated by NOAA and by the private Harbor Branch Oceanographic Institution. If the *USS Monitor* expedition is considered separately given its unique archeology and artifact recovery missions, the remaining OE program field season provided or leveraged eight ships and visited 17 unique geographic areas while spending approximately 190 cumulative days at sea, a simple average of about 11 days of ship time for each non-archeological area of interest. Direct costs to the OE program for ship capacity to support its expeditions ranged from zero in the case of selected NOAA vessels—with operating and maintenance costs covered by NOAA—to a rate approaching $1M for 30 days of access to the deployed, deep-diving capabilities offered by a Class I vessel and equipment suite analogous to the *R/V Atlantis* and the *Alvin* submersible operated by the Woods Hole Oceanographic Institution.

A simple extrapolation of ship capacity requirements to satisfy the subset of total exploration needs identified, including those related to marine archeology, leads to the conclusion that a number of days of ship time on the order of 10,000 would be required to conduct ocean exploration activities at the interest areas identified during the workshops. This estimate of required ship time is likely quite low due to the following reasons:

- Some of the general regions of interest are quite expansive and are guaranteed to include multiple sites where subsequent exploration activities will be desired
- Many of the sites of interest are geographically distant and are beyond the scope of the existing OE program (e.g., the Mid-Atlantic Ridge, Micronesia and the Pan-Pacific, etc.)
- The workshop participants represented only a subset of the total ocean exploration stakeholder community, thus the identified sites of interest are likely to expand as this broader stakeholder community becomes engaged in the program
- To achieve the multidisciplinary benefits desired by exploration stakeholders, extended time-on-station at many sites will be required
- National areas of interest identified in the *Frontier Report,* such as the expanse of the Southern Ocean, were not identified during the course of the workshops

Despite the fact that the estimated requirement for ship capacity is fairly conservative, it represents a demand for resources in excess of $300M for time aboard non-NOAA vessels meeting the minimum "standard package" capabilities identified by the workshop participants. By comparison, initial OE program budget estimates in December 2001 for ship time during 2002 field season, with 85 days of projected NOAA ship time—75 days in partnership with the National Marine Sanctuaries aboard the *R/V McArthur* and 10 days on the *R/V Ron Brown*—and based on the current year $14M total program budget, included approximately $3.5M for an estimated 250 days of ship time supporting exploration activities. These figures do not include the leveraging of Navy assets supporting continuing artifact recovery at the *USS Monitor* site. Given the existing availability of government-owned vessels and the program's funding level, the OE program would require about 90 years to complete a single expedition to each of the target areas of interest identified by workshop participants, assuming all geographically distant sites were accessible.

A specific recommendation contained within the *Frontier Report* is the completion of a multi-year voyage of discovery as a signature mission.[9] Although not addressed in detail

by workshop participants as a specific need, it is evident that a vessel dedicated to this mission would be capable of satisfying many of the needs identified within this report and would be able to bring a large number of the distant sites of interest into range. From an operational perspective, a dedicated vessel could provide as many as 280 additional operational days at sea each year. Relative to program costs, such a vessel would free up considerable OE program funding for direct application against investigator proposals and technology development needs, expand the program's capacity to meet the requirements of the stakeholder community and those stated within the *Frontier Report*, and provide a large benefit/cost ratio for NOAA as funding formerly required to cover the costs of ship time aboard non-government vessels is redirected to OE program activities and participants. A dedicated vessel would provide a platform capable of supporting permanent integration of supporting technologies and a concurrent enhancement in capabilities. It would also facilitate the establishment of an extended partnership with a broadcast or film media group of national or international scope—one that is certain to seek continuity in the environment, equipment, and participants so that viewers have the opportunity to establish familiarity with the surroundings and virtual relationships with the explorers.

4.2.2 Technology Development

Participants in each of the eight regional workshops identified a broad range of technologies associated with companion approaches for satisfying ocean exploration needs. The candidate areas for technology development were nominated based on their potential to facilitate satisfaction of each need and were not examined in greater individual detail by the workshop participants due to the other time demands of the workshop process. Technologies identified by each region appear within the tables provided in Section 3 and have been summarized in this section by categorizing them and eliminating clearly duplicative technology needs. The results of this process are provided in Table 4-2. No attempt has been made to prioritize the technology areas listed in this table. Desired actions related to the technology areas identified by workshop participants are divided into three categories. Several of the identified technologies are candidates for multiple categories—for example, tailored AUVs for archeological assessment are appropriate in either the Platforms or Marine Archeology categories—but are listed only

once within the most representative category (in this case, Marine Archeology). The perceived target of potential future investments distinguishes the definitions of these categories:

- *New Development.* Investments are required to develop fundamentally new technologies that provide innovative ocean exploration capabilities to meet emerging needs
- *Improve Capability.* Investments are required to enhance the ability of emerging and existing technologies to meet evolving ocean exploration needs
- *Expand Capacity.* The required technologies exist; however, investments are needed to facilitate increased access by ocean explorers to these technologies

Table 4-2. Regional Workshop Technology Needs

Category	Desired Action	Technology
Communications	Improve Capability	remote data link
	Expand Capacity	maritime communications services real-time information transfer broadband communications
Data Processing	New Development	conversion of molecular data to signals
	Improve Capability	Automated Wrecks & Obstructions Information System (AWOIS) data processing and visualization tools digital ID tools digital process annotation fingerprinting technology Geographic Information Systems (GIS) intelligent agents processing/visualization tools visualization techniques
Genomics	New Development	genetic markers genomics on a chip
	Improve Capability	biochemical genetic screening molecular systematics genetics (method to measure diversity) DNA storage technologies faster genomic technologies (shipboard) genetic sampling real-time remote analysis of genomics
Human Diving	Improve Capability	cold water diving rebreathers/mixed gas
	Expand Capacity	saturation diving technical and advanced diving
Human Habitats	New Development	mobile habitats
	Expand Capacity	Aquarius and other habitats long term observatory

Category	Desired Action	Technology
Imagery and Video	New Development	acoustic/laser vision systems Cave Cam (access through cracks & small openings) self cleaning camera lenses
	Improve Capability	confocal microscopy Critter Cam digital camera systems digital cameras HDTV & holography image recognition and software IR laser scan laser imaging light meters and other monitoring equipment low light cameras motion sensor cameras photomosaics rugged low light cameras strobe frame photography for time series analysis thermal imaging time lapse imagery tomography video image classification techniques
Marine Archeology	New Development	facilities for preservation & stabilization of artifacts tailored AUV for archeological assessment
	Improve Capability	archeological tools artifact removal tools non-destructive investigation techniques shipwreck integrity tools
Other Data Sources	Expand Capacity	ARGOS Hawaii Undersea GeoObservatory (HUGO) at Loihi volcano hyperspectral imaging from aircraft National Technical Means SABSOON network expansion

Category	Desired Action	Technology
Platforms	New Development	AUV "garage" AUV stationed underwater - "wake up" AUVs that follow targets dedicated submarine dedicated swath vessel deep ROV/AUV (multipurpose) deep submersible high current-capable submersible networked AUVs next generation of FLIP NR-1 submarine-like vessel
	Improve Capability	adaptable control systems deep ROV dockable AUV's radio-acoustic positioning telemetry (RAPT) remote sensing technology on AUV ROV/AUV dynamic positioning systems slow moving, steady AUVs tailored AUV
	Expand Capacity	aerial survey Alvin and deep ROVs in inventory AUVs for mapping broad shallow areas of continental shelf dedicated ice breakers & ice capable vessels extended AUV range capability submersibles vessels of opportunity
Sampling - Biological	New Development	automatic release, pop-up fishing gear and sensors high pressure sample preservation migrating instruments miniaturized samplers reusable biosensors tracking biota with space-based remote sensors sampling tools to collect gelatinous organisms
	Improve Capability	AUV/ROV bait deployment bioprospecting tools capturing particle flux flow cytometers for microbe levels hyper-/multi-spectral optics (species ID) larval sampling tools measurement of energy flow thru life form systems non-invasive technologies to follow mammals nutrient sensors optical plankton counter phosphorescence sensors remote biota capture techniques sampling & stable isotope analyses for food pathways sampling and incubation systems for culturing organisms specialized tows for zooplankton upward looking devices to monitor water column water sampling, virology, bacteriology, molecular biology techniques

Category	Desired Action	Technology
Sampling - Chemical	New Development	microchemical sensors molecular level diagnostics and early warning
	Improve Capability	active fluorescence chemical characterization of sites using cores chemical sniffers environmental tracers fatty acid analysis gas hydrate sensors geochemical measuring systems higher resolution chemical sensors neutrally buoyant chemostats optical spectrometer sensors for gas analysis
	Expand Capacity	long term chemical sampling (e.g. osmosamplers)
Sampling - Geological	Improve Capability	geologic porosity instruments remote drilling pressurized hydrate cores
Sampling - Physical	New Development	adaptive sampling instruments laser linescan technologies to direct sampling surface deployed, deep sampling/analysis devices
	Improve Capability	corers/vibracorers deep ocean sampling instruments drifting sediment traps (vertex style) improved suction samplers neutrally buoyant sediment traps nuclear magnetic resonance for sediment analysis remote manipulator rock dredging sediment coring sediment traps smaller tools (bore hole size)
Sensors - Acoustic	New Development	acoustic techniques for benthic classification synthetic aperture sonar
	Improve Capability	acoustic biomass acoustic imaging of sediment layers acoustic mapping (single/multibeam) acoustic monitoring (biologics and geologics) acoustic tagging of biota better/faster multibeam systems forward scatter acoustic techniques interferometric sidescan sonar multibeam bathymetry towed arrays
	Expand Capacity	ADCP's sidescan sonar SOSUS

Category	Desired Action	Technology
Sensors - Deployed	New Development	instrumented "rock"
	Improve Capability	3-D/4-D seismic buoy networks drifters (SVP) ice moorings instrumented moorings long-term moorings multi-line arrays and multi-sensor arrays remote sensors for marine mammals satellite tags on spawning fish
	Expand Capacity	permanently moored data buoys seismometers
Sensors - General	New Development	automated sensors hyperspectral techniques intelligent sensors micro- and nano-technologies miniaturized exploration / sampling techniques small scale air/sea interaction sensors
	Improve Capability	flow thru system gravity survey heterogeneous area sampling improved RADAR and LIDAR magnetic sensors mass spectrometry plume prospecting sensors pop-up satellite archival tags (PSATS) profilant floats radiological sensors resistivity sensors salinity measurements sea-floor probes sub-bottom profiling towed geo/chem/bio sensors vertical array sensors water column sampling
Sensors - Hardened	New Development	heat flow sensors extreme cold technology
	Improve Capability	biophysical moorings (winter) low temperature containers high temperature sensors
Sensors - Hull Mounted	New Development	bow mounted microwave radar
	Improve Capability	shallow water fathometers

Participants in multiple regional workshops identified common ocean exploration technology needs. This set of technologies likely represents the highest collective priority among the workshop participants and may be considered representative of the interests of a multidisciplinary group of ocean exploration advocates. These common interest technologies are included within the following themes, listed without regard to priority:

- AUV technologies including associated sensors and tools, command and control capabilities, communications, navigation systems, and deployment and recovery mechanisms
- Deep diving (greater than 4500 meters) submersible and ROV assets
- Dedicated surface-based exploration platforms
- New and expanded high resolution (~1 meter horizontal and 0.01 meter vertical) bathymetric mapping technologies
- New high resolution digital imagery and video technologies in natural lighting conditions and in a variety of electromagnetic spectral bands
- New and improved miniaturized, adaptive, tailored, and remotely or robotically operated tools for physical, biological, geological, and chemical sampling
- New tools for archeological assessment, artifact recovery, and preservation
- Innovative in-situ and remote sensors and tools to support genomic, biotechnical, bioengineering, and microbiological applications
- Improved precise positioning systems for platforms, vehicles, and deployed sensors
- New and improved sensors designed for use in extreme environments
- Systems supporting increased depths and residence times for human diving
- Intelligent sensors for detecting, characterizing, and tracking pelagic biota
- Improved data collection, processing, and visualization capabilities

4.3 Benefits

This section summarizes the potential benefits to be gained through the satisfaction of ocean exploration needs from the perspectives of the workshop participants. The benefits were derived from discussions relating to the relevance of specific exploration needs, and the resulting information in this section has been consolidated and standardized from the raw workshop data. The benefits have been organized within the themes of science, industry, outreach, and regulatory policy. This section provides a detailed summary of these benefits by theme, followed by a consolidated, categorical listing in Table 4.3.

4.3.1 Scientific Benefits

The scientific benefits include advances in science knowledge from exploration that lead researchers, technologists, and others towards asking the right questions and guide them to solutions. Ocean exploration provides information in undocumented or unknown areas of science to allow comparisons and definitions of changes to the planet. The lack of

documentation and inventory of the complete environment and insufficient high-resolution maps of oceans and coastal areas were the most frequently mentioned needs for conducting exploration. Scientific benefits were discussed more than other benefits and generated the most response due to the professional backgrounds of workshop attendees. The benefits are provided by exploration needs category in alphabetical order.

- *Archeology.* Archeological benefits include, but are not limited to, knowledge of historical effects of anthropogenic influences on ocean resources including rate of change, the chronological record of mankind and its exploitation of the sea, and historical migration routes of humans. Discovering the historical record also includes identification of potential cleanup sites, protection of historical sites, and identification of paleo-sea level changes. Archeological pursuits help to refine questions about where the human culture is heading and identifies socioeconomic and cultural use of the oceans in the past so that its past use on present ocean conditions can be determined.

- *Artificial Reefs.* Exploring artificial reefs leads to discoveries of the interactions between reefs and their environments and helps characterize the identity and distribution of biota and invasive species. It also supports an understanding of the role of ocean and coastal underwater structures and how they affect the life cycle of fisheries.

- *Benthic Regions.* Benthic regions are difficult to observe and thus are not well understood. The discovery of new benthic species is nearly certain, along with information exposing the earth's history and proxies for understanding sediment records and crustal processes. These regions also provide a link to understanding climate change. Exploration of the bottom can lead to an understanding of the reasons for failing fisheries and dependencies in fragile ecosystems such as the Great Lakes. Exploration can produce knowledge of bottom dwelling fish in the food web, including their life cycle and processes that may be limiting recruitment. Placing the deep Gulf of Mexico into zoogeographic context may generate biotech applications and help define genetic makeup.

- *Air-Sea Interface, Currents, and Water Masses.* Air and sea interaction, currents, and circulation are drivers of ocean changes. Ocean exploration provides an ability to assess impacts of these changes on habitats, ecosystems, productivity and eventually global climate change and other global processes. These assessments can be accomplished at macro and microbial scales. The ability to assess these impacts requires observations that have not been collected before. Data from exploration activities can drive the development of ocean prediction and circulation models (small scale processes in the water and air). Using lakes (e.g., Great Lakes) as a model of a closed system will allow for logistically easier study of climate impacts and the transport of toxics and nutrients. Relevance to societal needs (e.g. global warming to trend prediction) is also a benefit. Exploration facilitates tracking of

biological changes and food production (larval transport), and provides a way to bring together the modelers and researchers conducting empirical measurements (pattern recognition). In the Arctic, little is known about one of largest nearly fresh water reservoirs (a gyre) capable of influencing global climate. Unknown species and processes, and nutrient distributions are characteristics of these gyres that help to understand transportation of fish populations and other organisms. The information also helps to understand and predict biohazard and geohazard events, as well as conduct impact assessments

- *Coral Reefs.* Conducting a complete inventory and mapping of deep and shallow coral reefs is an exploration mission with many short and long term benefits. They include understanding the trophic connections, impacts of diseases, and the role of corals as ecosystems and as commercial fisheries habitats. This knowledge can assist in management of these areas leading to enhanced species diversity. New species will be identified. Extremely cool, and very old deep coral information will contain excellent deep-sea climate records (deep sea climate gradients) and are loaded with bioactive chemicals. Corals are also the centers of biodiversity in shallow waters and a target for genomic studies to support bioengineering.

- *Ecosystems in Abrupt Topography.* The benefits of exploration of ecosystems in abrupt topography regions were of high interest during the workshops. There is a lack of basic spatial and temporal understanding of ecosystems. Inventories associated with ocean exploration could populate a considerable number of information gaps. Oceanographic research programs overlook many remote areas with highly variable habitats. Ecosystem inventories would support data collection needs in biodiversity, ecosystem interactions, biological community structure, and management and restoration issues. Inventories will identify pollutants and their sources and transport mechanisms. From inventories of possible resources in shallow water to unexplored dynamics of the nephaloid layer, new information on deep water coral communities, baroclinic effects, nutrient production, and biological productivity will contribute to new discoveries about many different and unusual ecosystems.

  Systematic changes occur along island chains due to their shape while other abrupt areas force very dynamic changes on the physical environment. The abrupt topography regions include geographic features such as arcs, canyons, canyon systems, depression areas, major subduction zones and trenches, fjords, submarine seamounts, ridges, associated unknown biological hot spots, ridges in heterogeneous lakes, pinnacles, and reef edges. Also included are vents, seeps, volcanoes and marine caves. Knowledge of impact of seamounts on ocean dynamics is another unknown area with influences on ocean circulation. A unique gravel cobble bottom feature and associated habitat is an example of a continuous feature that is not well documented. Ecosystem exploration in abrupt topography regions provides benefits to the understanding of submarine volcanism, strong current habitats, animal migration issues, and other intense fisheries issues. This exploration is key to understanding the distribution of sediments, the knowledge of depositional cycles, the impacts on marine mammals and nutrient production, and the knowledge to resolve history of continental margins, and effects on oceanography and biological assemblages.

Exploration inventories of abrupt topography regions in geological, topological and biological coupling, foraging, and upwelling helps to explain facets of maritime geologic history and particularly Pacific plate evolution. Emerging landscapes are often extremely dynamic with many opportunities to leverage off of other studies in these areas. Unique ecosystems, species, trophic systems and food webs thrive in centers of upwelling. There are also recolonization issues, such as following a biologically related catastrophe. Fundamental dynamics knowledge is needed for understanding roles of these regions as biogeographic "stepping stones". Discovering the biodiversity of these areas can also lead to potential conservation areas.

There is significant potential for hydrothermal activity at troughs. Workshop participants felt it important to understand equilibrium in the untouched communities of troughs before disruption, trying to understand how they evolved thru time by measuring the duration of settlements in any one spot. Discoveries could include unique species with bioengineering potential.

Trenches and Arcs, although similar to troughs, were a major emphasis in the Hawaii and Alaska regions. Discoveries of gas hydrates, chemical plumes and fluxes and unusual biota are expected in the Tonga Trench and Tonga Kermadec (less than 2% has been explored). Mapping and inventories of volumetrics, geologic signatures, ocean circulation vectors, plate tectonic boundaries, the deep water column as well as the subduction factory will reveal mineral resources, and variations of biomass in an oasis of life. These types of areas are huge opportunities for fundamental discovery of bioactive compounds, health in the deeper coastal zone, biotechnology, genome mapping and modes of life.

Other abrupt topography regions of interest are marine caves, vents, seeps and volcanoes and other extreme environments. Vents seeps and volcanoes are similar to marine caves as unknown areas with very little information on their distribution. Inventories of all taxa, living fossils, and biodiversity will discover unknown exotic organisms and new links and insight into the deep sea and the evolution of life. Every vent appears to be a bit different with most species endemic but exhibiting an extensive biodiversity. Knowledge of them is key to understanding active volcanoes, gas chemistry, and hydrothermal geography. New knowledge of genetic links between biota from different areas will provide fundamentally new insights into evolutionary science.

- *Ecosystems in Basins and Banks.* Exploration in banks leading to basins that go to great depths over short distances will reveal large amounts of interesting information regarding geology, shipwrecks, carbonate bank evolution and unknown “whiting events” possibly from calcium carbonate in the water column. Inventory of fisheries will provide connectivity and species dispersal to other unexplored regions. Other benefits include clues to sea level change, general coral reef health information, history of major islands such as Hawaii, and identification of new habitats. Other areas that are not well documented include Alaska’s glacial scoured areas and channels.

- *Ecosystems in Extreme Environments-Sea Ice.* Sea ice areas and the marginal ice zone are not well understood and have important biological potential. Exploration will identify new species and novel protection mechanisms against extreme conditions. Many birds and mammals spend winter in the Bering Sea and Aleutian Islands but little is known about their food web dynamics. The Alaska workshop participants consider Bering Sea ecosystems to be at risk due to diminishing annual extent of sea ice, which is believed to play a critical role in the shelf ecosystems. There is an unknown balance of physical and biological processes associated with ice dynamics and changes in ice distribution for climate response issues will benefit from exploration.

- *Ecosystems in Lakes.* Large lakes are a major resource for fresh water. The Great Lakes have considerable deep and bottom areas that are largely unexplored. Benefits from exploration include finding and understanding new species and understanding the origin of the lakes themselves. River run-off, linkages between estuaries and river fauna, biota and their habitats, complexity issues unique to the freshwater lakes systems, and potential sources of groundwater input are important to science and our way of life. The unique and unknown evolutionary aspects of microbiology in fresh water lakes may help in bioremediation. Ring depressions are largely unexplored yet are the most widespread feature on the floor of North America's largest lake.

- *Ecosystems near Shorelines, Ledges, and Slopes.* These ecosystems are significantly impacted by humans and not documented nor inventoried enough to help scientists ask the right questions. The remote nature (Alaska) and the unique meeting of water currents (South Atlantic) are examples of productive areas for exploration. Baseline inventories and surveys will provide information for hurricane impacts (coastal hazards such as erosion, rapid response to natural or man-made catastrophic events), essential fish habitat knowledge, and paleoshorelines including coastal evolution, knowledge of substrate, benthos, habitats and their relationships. Understanding of unknown ecological systems, behaviors, energy flow, status and impact assessments, bottom health, and flux of nutrients will contribute greatly to defining and locating future Marine Protected Areas and their functionality. New knowledge and a better understanding of slopes will serve to benefit impact assessments, identify new species and biodiversity, identify upwelling zones, and provide a baseline characterization of productive areas for essential fish habitats. Knowledge from exploration will also assist in the understanding of the influence of the Gulf Stream.

- *Episodic Events.* Information from exploration of episodic events would be collected on event driven storms, surface and benthic storms, algal blooms, distribution of nutrients, coastal processes, the synergy of impacts and mitigation, hypoxia phenomenon, and currents related to the formation of harmful algal blooms. Benefits derived from a plate scale to mesoscale (gyre scale) observatory for long-term understanding of episodic events would open a new temporal domain, resolves limitations of surface vessels, and establishes a new paradigm of sampling in time and space providing an interactive telescope into inner space.

- *Geology and Geomorphology.* The areas of plate boundaries, strike-slip systems, glaciers, and the characteristics of the environment created from glaciers are not well understood. The fresh water inputs to the ocean and consequences of rapid glacier retreat are also not well documented. An examination of variability in the global record is needed to help determine if human activity is changing our environment. High-resolution maps are required to identify and characterize shorelines and reefs, develop baselines for geology, and to locate other important geomorphologic features. Benefits include the identity of mass-gravity movement, turbidity flows, hydrate beds, slope instability, paleoclimate changes, sea floor habitats, beach deposits, canyon formation processes, and anthropogenic factors. Exploring the megafurrows in Gulf of Mexico and Great Lakes can provide impact on currents, sediment transport and habitat issues. Other benefits are possible from higher resolution surveys such as the discovery of new features and biota, new essential fish habitats, new lake processes and boundary conditions and insights into deep-water circulation and sedimentation patterns.

- *Human Impacts.* Workshop participants discussed exploration into the human impacts on the ocean as a significant impact on the health of the planet, from ecosystems health to the impacts of anthropogenic noise. The science of understanding human impacts may resolve information relating to competition for resources and habitat loss and degradation of fishing. Exploring natural and anthropogenic noise can lead to use of natural noise as a measure of ecosystem and constituent health.

- *Marine Conservation.* Little is known about proposed marine reserve regions. Most are deep regions, greater than 50 meters depth, and have a role in supporting ecosystem spawning. Knowledge of these proposed areas from exploration has many benefits, particularly related to regulation. For example, exploration could reveal impacts such as the destruction of deep corals in the Oculina Banks from trawling and dredging, in this case leading to designation as a Marine Protected Area and closure to fishing. Exploring this area and others like it will provide knowledge of unique habitats and an assessment of restoration techniques. More knowledge is needed to demonstrate the effectiveness of Marine Protected Areas in restoring corals and fish populations.

- *Marine Microorganisms.* Fine scale knowledge of microbes is an important objective for ocean exploration. They are the most abundant organisms in the marine environment, playing a critical role in the function of ecosystems and the control of biogeochemical cycling. Knowledge of microscopic interactions and microbial roles in ecosystems will benefit science in knowledge of ecosystem health, long-term variability, production of biochemical compounds, and changes affecting ocean productivity. Exploration will help in documenting the life cycle of parasites, primary and secondary hosts, and improve the knowledge of their effects on carbon and phosphorus cycling.

- *Marine Organisms.* Data gathered from exploration will benefit knowledge of migration patterns for high-latitude organisms, how animals use vision & light to

orient themselves in the water, populations in flux, biological transitions zones, understanding exotic invasive species, and the distribution, migration, and abundance of gelatinous plankton. Knowledge of these organisms will help to identify critical habitats, their utilization, and will help identify global climate change. A taxonomy inventory is necessary to determine the marine biodiversity and ensure the benefit of preservation of species. Benefits will be derived from new knowledge of novel feeding relationships, survivability, and genetic and chemical diversity. New feeding relationships could reveal major sources of nutrition and lead to new biological linkages. Workshop participants principally discussed macro organisms, but recognized that pelagic plankton represented the dominant biomass in the ocean.

Exploration can benefit fish populations and fisheries by the scientific knowledge gained. Discovering and collecting information about distribution of marine geographic endemics, abyssal fish, fish evolution in isolation, inter-lake comparisons, and species migration can benefit the management of newly discovered or exploited species. Little is known about gene flow problems, recruitment problems, larval dispersal, distribution, and stages, invasive species problems, displacement behavior, life cycle and history, impacts of the amphipod diporeia decline, and island and region biogeography. The benefit of understanding the importance of upwelling will help to explain or predict recruitment to fisheries, effects on estuarine systems, define unique habitats and locations, and understand the dynamics of fisheries and ecosystems.

Exploration of marine mammals includes discovering and collecting information about distribution, movement and behavior patterns, orientation, and abundance of deep diving and long-range mammals. Additional benefits include information about food sources and distribution linkage including vertical migrations, habitats of large pelagic animals, the identity of obscure, unknown animals, population success rates, interactions with ocean structures, and use of habitat and navigation mechanisms.

- *Ocean Resources – Bioprospecting and Minerals.* Bioprospecting has benefits to both scientific and industry. There is a high likelihood of bioprospecting success from knowledge of the local biodiversity and molecular content in around coral reefs and other remote ocean regions. An inventory will provide baseline knowledge of candidate locations for further study. Knowledge of renewable resources such as gas hydrates and the discovery of deep sea minerals support knowledge of the impacts of these resources on climate change, carbon cycle, geohazards and sea floor stability, and fluxes of material through the sea floor.

- *Pelagic Environments.* Mid-water exploration can lead to significant benefits, particularly the identification and characterization of the largest ecosystem and biomass in existence. This exploration can also help define the composition of the pelagic realm and resources that need to be conserved or exploited. Other benefits include discovering unknown interactions in the water column, new species, carbon cycles processes, baseline data for rapid response to blooms, micro level knowledge of ocean processes, contributions to the food web, and knowledge of spawning and distribution patterns.

- *Sound in the Ocean.* Characterizing naturally occurring sounds in the ocean and using the technology of acoustics to support exploration can lead to new discoveries across all of the oceanographic disciplines. It will also support the development of innovative sensor systems.

4.3.2 Outreach Benefits

Outreach benefits are centered on education of the public of our marine environment so as to ensure its proper use and conservation through stewardship. Education of maritime and marine history, technologies in use in the ocean, and effective preservation methods were emphasized in the workshop discussions.

- *Education.* Education specifically includes targeted efforts towards K-12, undergraduate, and graduate level students. The products of ocean exploration are very visual and provide the media, academia, and industry with the material to educate the population and support a robust tourism, ecotourism and water quality industry as well. The adventure of exploration can excite the public by showcasing a "new frontier" that emphasizes the discovery of new organisms, biotechnology development, and new areas of research. Through the Ocean Explorer web site and related sites, expanding computer literacy can be associated and related to science. Other vehicles for outreach include opportunities aboard cruise ships for educational lessons. Opportunities must be organized to get students and teachers out to sea in relevant regions. The education of entire communities may be possible by tailoring public education, such as by encouraging graduate students to focus on ocean issues of local public concern. Data from ocean exploration can be incorporated into curricula such as geographic information system classes. Additional opportunities exist with public interest in the history of Hawaii regarding extreme environments as attractive and unusual topics for media and education.

- *Stewardship.* Stewardship of our cultural resources was included as a significant benefit from exploring our ocean's potential and existing historical sites. Strong education initiatives will build the core public interest towards stewardship of the ocean environments and merge with public safety issues about the oceans and beaches. This issue has some visibility with the public through publicity about invasive species and harmful algal blooms. The public also has an interest in biotechnology products, beach recreation, fishing, pharmaceutical potential of marine resources, biological warfare against infrastructure assets such as power plants (e.g. zebra mussel issue), operation of municipal water plants, and even carbon cycling. Knowledge gained through exploration may appease public concerns and activate mitigation efforts towards safety-related ocean issues such as tsunami predictions, fisheries sustainment, and unauthorized dredging. Conservation of the environment can be sustained through effective and safe use of newly discovered deep-sea natural resources.

4.3.3 Industry Benefits

Industry benefits include improvements in capabilities, expanded products and markets, more economical methods of doing business, and improved safety in the ocean environment. These benefits also indirectly expand the public interest in the ocean and its potential. Ocean exploration will support technology development in a wide range of industries including those related to water resources, tourism, fisheries, bioprospecting, and energy.

- *Water Resources.* A unique connection between industry and scientific knowledge is the importance of understanding fresh water resources. The dynamics of lake environments and their freshwater resources were emphasized in the Great Lakes workshop since these lakes contain most of the fresh water resources of the world. Physical oceanography knowledge gained through exploration leads to an understanding of many ocean and lake processes. Water level variations of the Great lakes can significantly impact navigation and the commercial shipping industry. Exploration data could benefit the interests of entities seeking knowledge of the Arctic's potential to support routine commercial shipping.

- *Tourism.* The products of ocean exploration are visually appealing and provide the media industry with material to educate and support a robust tourism industry. Industries that may benefit from these products include sport fishing, recreational fishing, diving, beach maintenance, cruise lines, and ecotourism.

- *Fisheries.* Knowledge of deep-water fisheries, inventories of fish habitats, and identification of new species will aid in building linkages between commercial and recreational fishing interests. Ocean exploration data will aid in applying fundamental ecological principles to the establishment of new fisheries and general fisheries resources. The SAFMC (South Atlantic Fishery Management Council) was identified as a direct beneficiary of ocean exploration information. Fisheries management benefits from exploration data through better stock assessments and understanding essential fish habitats.

- *Bioprospecting.* Exploration data has huge potential to provide many advances in biotechnology and its applications to the pharmaceutical and seafood industries. Genome mapping, discovery of modes of life and biotoxins, and a wealth of other information may be available. Unique species with biochemical properties may serve as areas of production "oases" for new bioengineering products. Bioprospecting, habitat mapping, and discovery of new natural resources will also benefit ocean resource management.

- *Oil and Gas.* The energy industry will benefit from the improved baseline knowledge of the seafloor and its natural resources. There is particular interest in areas where ecosystem management and restoration issues are critical to sustainable

environments. These issues are coupled with the potential discovery of new natural resources. There is general recognition that methane deposits in the form of hydrates could have huge potential as an energy resource if they could be recovered economically. Other important mineral resources may be discovered as well. Possible coldwater petroleum seeps might be discovered in unexplored areas near abrupt topography. The Gulf of Mexico may be unique with amount of oil naturally occurring in this region.

- *Other Economics.* The cost of business for the communications industry will improve from the use of exploration data for cable laying efforts. Aquaculture will benefit from the scientific data collected from ocean exploration. New business is likely to develop around new opportunities resulting from ocean exploration efforts.

4.3.4 Regulatory Benefits

The process of developing regulations, policies, and legal mandates can be accomplished more easily and correctly as a result of the benefits of ocean exploration. Specific benefits include properly prioritizing sites for recreational, archeological, historical purposes, nominating designations to the national register, and cultural resource management.

- *Marine Protected Areas.* Marine Protected Areas contain critical ecosystems, important resources of high trophic-level organisms, and are subject to controversial fishery restrictions. Inventories and knowledge of these areas gained through exploration will be critical to the regulatory process.

- *Fisheries.* Ocean exploration information will provide a better ability to monitor the impact of fishing and other disturbances on fisheries to provide for better protection and management of sustainable fisheries. The deep ocean will reveal new benthic fish populations. Some species may be endangered and ocean exploration data can assist in determining the effectiveness of fishing restrictions, the seasonality of fishing areas, safety measures, and expected costs of containment controls such as structures and artificial reefs. These efforts support the Endangered Species Act, the Marine Mammals Protection Act, and the Census of Marine Life (CoML).

- *Conservation.* The conservation of natural resources requiring protection and sustainability will benefit from ocean exploration data. Some of these areas have the largest information gap and therefore have huge management implications. Coastal areas need protection from storm surge, loss of wetlands, and encroaching habitats. Information on water quality, contaminants, and marine ecosystem health will ensure that constituents and coastal zone managers have sufficient knowledge to support correct management and enforcement policies. International policy cooperation is also necessary and dependent upon ocean exploration data for information related to the impacts of waste dumping and other practices. Ocean exploration information can

benefit a wide range of other regulatory efforts with social and economic relevance such as regulation of shipwrecks, safety of life and property, pollution impacts, remediation of habitats, counteracting bioterrorism, and homeland security. Public health regulations and land use polices governing watersheds and coastal erosion zones will also benefit.

Table 4-3. Regional Workshop Exploration Benefits

Category	Workshop	Exploration Targets	Description	Benefits
Archeology	Regions: Alaska Caribbean Gulf of Mexico North Atlantic West Coast	Submerged cultural resources and maritime cultural environment; Shipwrecks including, pre WWII, WWII and Later Human Sites, Archeological Information on Human Migration, and basin and human interactions	Regional Archeological Assessment: Location, inventory and characterization of historical sites; documentation of artifacts and ancient villages; document effects on ecosystems and food chain, migration routes, dump sites; Document ice records. Characterize by Biological / Geological / Chemical; Document status of wrecks; recently uncovered by storms, etc. using systematic surveys or target submersible historical shipping lanes; sub-bottom formation identification of targets; consistent survey of coastline areas out to EEZ, record of sea level change; photo documentation;	**Scientific:** To assess effect of anthropogenic factors on ocean resources; Document chronological record of "mankind in the sea", migration routes of humans, Identification of potential cleanup sites; protection of historical sites; paleo sea level changes-assess rate of change-how humans and environments respond; insight into development of technology; Caribbean colonization. Where are we heading? **Outreach:** education of marine history; more effective preservation methods; **Regulatory:** Legal mandates; prioritize sites for recreational, archeological, historical purposes; designations to national register; cultural resource management
Archeology	Regions: Great Lakes Hawaii	Cultural resources; Paleo Archeology of basin and human interactions - survey and documentation; Understanding population from geological records; Extinct species (fossil reefs) Understanding the human habitat	Identify shipwrecks; Submerged shorelines; Paleolake lines, ID sites, location, archeological documentation, evolution of marine technology, 19th century, effects on biology (good time measurement), influence of currents, Broad based survey; then document important sites; model storm data; Study fossil and carbonate samples and records, population over geologic time; Mapping	**Scientific:** From earliest archeological sites in region, obtain a better understanding of prehistoric life & technology; Industry Increase connections to fresh water and appreciation of Great Lakes resources; Understand dynamics of region, **Outreach:** public interest, K-Grad, unlimited, more for prehistoric, **Regulatory:** Largest density of shipwrecks & submerged cultural resources, need to be protected & managed

Category	Workshop	Exploration Targets	Description	Benefits
Archeology	Region: Hawaii Atlantic North	Submerged archeological sites; Natural history of Hawaiian Islands; Character of Deep Water and other Archeological sites; Shipwrecks (5-10K off New England); Shipwreck Aggregation Sites	Near-shore low impact visual survey - Targeted historical research, archives, non-invasive documentation, geological controls on marine biota and communities; Mid-water remote sensing - narrow down to select survey areas, Deep water - survey targeted areas then ground truth; structures; cultural resources; Priority to older targets; ID location, & characterize paleo geography	**Scientific:** - Not well documented; in state and federal laws that historic vessels are to be protected; Marine resources; Better maps; Hazards issue, Industry - tourism; salvage **Outreach:** - lots of public interest, education, stewardship of cultural resources; **Regulatory:** - mandate for protecting areas;
Artificial Habitats	Region: Great Lakes Gulf of Mexico	Artificial Reefs; Offshore man-made structures	Recruitment, deterioration of cultural material, environmental effect, new vs. used; Zoogeography of man-made offshore structures - oil and gas structures with time-based observations (depth is a very important component; systematic approach); oil and gas structures; Sargassum mat time-based observations at rigs (modeling; observe before and after mats pass rigs); taxonomy; diversity; distribution	**Scientific:** In fresh water can do well controlled experiments; How reefs interact w/environment? Characterization and distribution of biota; invasive species; understanding the role of these structures +/-; how do they affect the life-cycle of fisheries; are they just FAD's; little known **Industry:** aquaculture, recreational diving, biofouling research, charter boat industry (sport fishing); resource management; pro's and con's of platform removal; provide other options for platforms not in use; biotech applications; resource management **Outreach:** very visual &interesting to the public**. Regulatory:** depends on results, should they be doing it or not;

Category	Workshop	Exploration Targets	Description	Benefits
Benthic Environment	Region: Alaska Hawaii	Relationship of Benthic Features and Essential Fish Habitats; Infaunal organisms	Catalogue the distribution and abundance of the types of species that are in the mesopelagic zone; document the benthic habitats that support important ecosystem components including fish and rare or special species and essential fish habitats; Taxonomy, investigate sediment ecology	**Regulatory:** MPAs; fishery restrictions; critical ecosystem; important resources; critical resource of high trophic level organisms (big fish, birds, mammals)
Benthic Environment	Region: Great Lakes	Benthic Communities "Things that live between the rocks" - Limited sampling of difficult areas; Deep Reef systems; out crop reefs; Identify & characterize interaction, effects of exotics, impact of fisheries, compare w/ oceans, food web	Sampling of difficult areas; Deep Reef systems; out crop reefs; Identify & characterize interaction, effects of exotics, impact of fisheries, compare w/ oceans, food web; effects of exotics	**Scientific:** Undiscovered areas of bottom; finding new species in Great Lakes; Failing fisheries in lower Great Lakes, need to understand why: Lake Superior (untouched), fragile, have ignored benthic fishes in food web; knowing mating game, life history, what's limiting recruitment, learning more about diporeia decline. **Industry:** power plants (significant) (e.g. zebra mussel issue), municipal water plants, carbon cycling. **Outreach:** "huge", public concern, education need. **Regulatory:** fisheries management, water quality, contaminants

Category	Workshop	Exploration Targets	Description	Benefits
Benthic Environment	Region: Gulf of Mexico	Biology in deep benthos; Characterization of bottom habitats; infaunal organisms; Exploring the deep benthos for biological communities; broad scale characterization and inventory; genomic mapping - non-traditional; cataloguing for biotechnology; live bottom communities; match fish species with bottom character;	Ground truth via deep tow side scan sonar; deep Gulf of Mexico is most heavily studied soft bottom in world; sampling; trawls; subs; genetics; Gulf is a marginal basin - distinct zoogeographic province; mapping identifies hard surfaces - can't trawl or box core; so photo; ROV's; subs; geology important; non-chemosynthetic hard bottom poorly studied; looking for topographic highs; lithoherms; lophilia mounds; sink holes - topographic lows - have lots of fish and corals associated with them	**Scientific:** high likelihood of bioprospecting success; biodiversity; molecular; placing deep Gulf into zoogeographic context; biotech application; genetic makeup; **Industry:** Fishing stock assessment; Understanding essential fish habitats, bioprospecting; habitat mapping; government NIH; resource management; resource management; **Outreach:** new communities; sexy topic; can work this stuff into curriculums; video clips on internet;
Benthic Environment	Region: North Atlantic West Coast	Knowledge of Deep Benthic Community and abyssal plain	Not well documented Characterize, Biology, Geology, Bottom Interactions, Ecology Dynamics; Deep Cold Corals; Sweeping water column; Investigate by using Class I/II Vessel w/Acoustic Mapping; Dive Capability (ROV / AUV / Submersible) w/ Imagery / Video & Sampling Equipment (Not Only ROV / AUV / Sub); Multibeam; ADCP's; Precise Position System; Outreach Capability; Education Component - Fixed Sensors; Space-Base Remote Sensing; Biosphere at the seafloor	**Scientific:** Need to ascertain anthropogenic impacts; not well known, know how ocean works; discovery is guaranteed; earth's history; proxies to understand sediment records; simultaneous process documentation over a decade opens the door to millennium; crustal processes compared to other planes; link to climate change
Boundary Fluxes - Air/Sea	Region: Caribbean	Air/Sea Interactions on the small scale	Document the biological, chemical, and physical processes of the air/sea interface in high resolution over a small area	**Scientific:** Help us understand the uncertainties of global change and other global processes at the microbial level

Category	Workshop	Exploration Targets	Description	Benefits
Boundary Fluxes - Air/Sea	Region: Great Lakes	Linkage in the atmospheric forcing function; How climate varies in space and time Carbon Cycling in Lakes; primary productivity, Carbon accumulation, Carbon consumption, compare among lakes. Each lake is a comparative experiment	Forcing functions in atmosphere; Air/Sea interaction for the exchange of gas mass constitutes; Across all lakes, measure physical properties, real time chemical composition (monitor 5 places in one of the large lakes; see how lake responded over two years and choose detailed location and study eddies and zooplankton modeling); Application for marine boundary levels influences; Different processes to study and couple to ocean processes cores and eddy's (rings); Climate Changes on timescales of decades to millennium. Compare carbon cycling, primary productivity, and carbon accumulation, among lakes	**Scientific:** Driver of Ocean changes; Using the lakes as a closed system for the development of prediction models (small scale processes in the water and air); Easier to study (logistics) the effects of El Nino and global warming; Lake circulation and variation questions; Better understanding of sediment record for paleoclimate, transport of toxics & nutrients, fish recruitment. Relevance to societal needs (e.g. global warming to trend prediction), higher resolution than ocean cores; **Industry:** Lake level variations impact commercial shipping; **Outreach:** Education, Inspiring kids, Computer literacy related to science vs. games; Connection w/ boaters; **Regulatory:** Major impact on lake level and fisheries management, Tourism protection, Water resource management; Test hypothesis of carbon cycling.
Boundary Fluxes - Air/Sea	Region: Gulf of Mexico	Air/sea interactions; Dynamics of interaction between water masses	Understanding impact of significant weather (hurricanes; tropical cyclogenesis) on deep ocean; characterize ocean under severe weather and ocean bottom in real-time	**Scientific:** ability to assess impact on habitats; geomorphology; and ecosystems; has not been observed before; benthic recovery; determine if relationship between tracks and water; hurricanes generated in Gulf; short-term warnings; Currently understanding lacks sufficient scale and depth; Identify impact on productivity **Outreach:** education; science; **Regulatory:** risk assessment safety

Category	Workshop	Exploration Targets	Description	Benefits
Boundary Fluxes - Air/Sea	Region: Hawaii Caribbean	Climate Change; Impact of fresh water runoff & suspended/dissolved matter	Feedback of ocean change on biota - through observation approach time series with El Niño events: determine impacts on equatorial Pacific biological pump; long term; carbon fluxes in thermocline; Identify and quantity impact of fresh water runoff & suspended/dissolved matter	**Scientific:** Understanding biotic feedbacks on climate change; Predicting/modeling changes on impacts; Impact on ecosystems & habitats - Information on land use activities
Corals - Deep water	Region: Atlantic South Caribbean Gulf of Mexico Atlantic North West Coast	Deep sea coral mounts (oculina and lophilia); Distribution and status of deep water coral reefs and fish stocks; Knowledge of Deep and or Cold water Corals	Collect information on the distribution, taxonomy, abundance, condition, diversity, and size of deep corals and fish stocks; Assess threats and Map associated fauna; area; extent; size of mounds; new species; Investigate by using Class I/II Vessel w/Acoustic Mapping; Dive Capability (ROV / AUV / Submersible) w/ Imagery / Video & Sampling Equipment (Not Only ROV / AUV / Sub); Multibeam; ADCP's; Precise Position System	**Scientific:** bioprospecting, unknown, new species; Map and inventory deep reefs; trophic connections - how do they work?; Understanding of major commercial fishery habitat to assist in management; discover role in enhancing local species diversity; New species identification; Role in Ecosystems; Possible records of climate changes; Extremely cool; very old; contain excellent deep sea climate records (deep sea climate gradients); loaded with bioactive chemicals; **Outreach:** education such as live broadcasts, discover role in enhancing local species diversity; Regulatory; MPA implications; **Industry:** resource management

Category	Workshop	Exploration Targets	Description	Benefits
Corals - Shallow Water	Region: Caribbean Gulf of Mexico	Health and assessment of shallow water coral reefs; Turbid water coral communities	"Norms" (coral, fish, biomass) of condition for comparison; One time assessment; Presence and distribution; morphology	**Scientific:** - understanding of disease and impacts; biogeography; ground truth of remote images; center of biodiversity of shallow waters; emerging field of study; genetic info; influence of turbid water on benthos; Industry - fisheries; tourism; beaches; Major resource management issues; source of sediment for beaches, **Outreach:** Visible topic for media coverage
Currents & Water Masses	Region: Alaska West Coast	Circulation Survey: Need information on large-scale circulation and variability of Beaufort Gyre, Alaska; Need knowledge of ecosystem in primary & secondary fish production areas; understanding geochemical processes - target on eddies and bondaries of strong currents and upwelling	Document subsurface currents; Explore Beufort Gyre as largest freshwater (almost) reservoir; Collect water column, physical data; use satellite imagery; collection of mid/bottom biologics; net and bottom sampling; connecting bio/chem/geo technologies and processes; eddy processes; ID drivers of production; lagrangian perspective; food web; ID sources and sinks, time signatures, and effects of human induced substances. Biogeographic cycling; inputs and outputs cycling	**Scientific:** Better understand benthic organisms, Understand how nutrients are distributed, and one of largest nearly fresh water reservoirs capable of influencing global climate; Previously have been unable to explore the gyre; Unknown species and processes; impact assessment; expands satellite tracking capabilities and real-time video; transmit broadband data; understand processes on other planets; **Industry:** fisheries management; management of living marine resources.

Category	Workshop	Exploration Targets	Description	Benefits
Currents & Water Masses	Region: Atlantic North Atlantic South Gulf of Mexico	Mapping currents and eddies and their connection to vertical and horizontal components; Exploring Gulf Stream, Loop current, and Florida Current; Knowledge of offshore currents impact on structures.	ID circulation; temperature discontinuities; current velocities; pH levels, HAB formations; Characterize; map; habitat assessment; nutrient cycling; life history/reproductive biology/evolution of life history, strategies of fishes, frequency and importance to ecosystem productivity, relationship between ocean prop. and hydrate stability; Use moored current meters at multiple depths; sediment traps; release drifters regularly from position on the sea floor and use satellites to track them; release drifters regularly from position on the sea floor and use satellites to track them, ID impact on engineering and design of structures.	**Scientific:** Understand and predict geohazard events, transportation of fish populations and other organisms; ID shipwreck status; Don't know much about dynamics of the Gulf Stream; **Industry:** storm warning and hurricane prediction; fishery; recreation; tourism; diving community; **Outreach:** huge educational/public relations potential, HAB predictions, biotech products; **Regulatory:** effectiveness of no fishing areas, seasonality of fishing areas; safety and containment control (structures), conservation management; safety and costs of structures; homeland security

Category	Workshop	Exploration Targets	Description	Benefits
Currents & Water Masses	Region: Great Lakes Atlantic North	Mesoscale Eddies/Fronts/Rings - frequencies & importance; Current flow patterns, eddies, mixing process, impact on bio, frequency & importance to ecosystems productivity, chem props; Discover new bio / geo /chemical pathways (distribution in the physical sense); Knowledge of physical and biological processes	Identify current flow patterns, eddies, mixing process, impact on bio, frequency & importance to ecosystems productivity, chem props; Identify pathways for compounds; place sensors at areas of gradients (biologically dynamic areas); ID intersections between layers, relationships to biota; Air-Sea Patterns / Interactions Impact of bottom boundary; Archeological Application; Magnetic Sensors; Data Mining; Bottom mapping & characterization capability; Develop new sampling protocols; Use Multi Line Arrays and Multi Sensor Arrays	**Scientific:** Need to understand input on ecosystem and nutrient and sediment transport; inference of global warming, correlation productivity, gene flow, recruitment, impact on benthic communities; fish recruitment; What compounds are influencing the environmental from remote area; Mass balance understanding in the Great Lakes; Contaminant Transportation; Coastal Meteorological models (Ground Truthing); Marine Weather Predication; Fisheries. **Industry:** lake level variations greatly impacts commercial shipping directly. **Outreach:** std pkg, education, inspiring kids, computer literacy related to science vs. games. **Regulatory:** major impact on lake level and fisheries management, on tourism protection, on water resource management
Currents & Water Masses	Region: Great Lakes Hawaii	Coupling of Modeling and Measurements; Sample strategy/ bio / currents / Atmosphere models - Models can drive questions researchers to answers; Knowledge of changes to currents and internal waves.	Place sensors at areas of gradients, at biologically dynamic areas; track marine debris deposits. Determine food production distribution; Identify internal waves, and correlate tidal changes and other physical oceanography.	**Science:** Citizen science; Balance of empirical measurements with models; helps in planning with catch per unit effort; verifies the conceptual of the measurements that will be made; environmental predictions; tracking of biological changes food production (larval transport); provides a way to bring modelers and empirical measure researchers together (pattern recognition); physical modeling drives biology

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem	Region: Alaska Hawaii	Characterize Bering Sea Fish Habitats; Identifying ecologically critical habitats	Temporal / spatial observations; mapping; then direct observations; diversity; location; substrate type; visual information; reflected imagery; community structure; Locating critical habitats with Critter Cam (Animal borne camera) system; Use existing and historical information Use Bathymetry to understand sediments and habitat; Use hydrography for better understand of tidal data; Understand temporal nature of biology	**Scientific:** Lack basic information; Areas will not be looked at by other organizations; high variability habitat; Very important spatial gaps; Temporal gaps; Bristol Bay Alaska was home of most valued single species in world at one time; Hawaii: biogeography, biodiversity, ecosystem interactions, community structure, management, restoration; Oil and gas interest in the area; **Industry:** recreation, fisheries; **Regulatory:** reserves, management
Ecosystem - Abrupt Topography	Region: Alaska	Aleutian Arc	Examine the structural arc; Examine substrates and patterns of coral distribution; Document hydrothermal venting and volcanism; Document biodiversity, biology, and oceanography	**Scientific:** Understanding the geologically active areas that include submarine volcanism; Better understanding of strong current habitats and animal migration issues.

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: Alaska Gulf of Alaska Atlantic North Atlantic South Hawaii Gulf of Mexico West Coast	Canyons and Canyon Systems; Unknown depression areas and canyon processes	Document rate of the consumption of the physical plate, geochemistry, sediment transport, and volcanism; Examine biology of area, and hot springs seeps; Examine these very interconnected physical systems; Inventory and document geology (improved mapping), Identify turbidity flow, erosion, and structure, microbial communities and other organisms, geochemical origins and effects; Map; characterize; ID mineral distribution; gas and groundwater seeps, sediment fluxes; chemistry; upwelling; ground truth, habitat role in carbon cycling, areas of high productivity	**Scientific:** Important area that is poorly characterized; Very systematic changes occurring along island chains due to shape; Dynamic physical system; Key to understanding the distribution of sediments; knowledge of depositional cycles; impacts on marine mammals; nutrient production; Is human activity changing the Gulf? Effects on adjacent ecosystems; unknown microbial communities and pelagic communities; origin unknown; inventory and characterize; potential for unexpected discoveries; Gulf characterized as a brine system - could be global question. Unique isolated habitats; resolve history of continental margins, and effects on oceanography and biological assemblages. History of Hawaii, Identify new habitats; **Industry:** fisheries, minerals, biotechnology; **Outreach:** public interest, lots of opportunity
Ecosystem - Abrupt Topography	Region: Alaska	Fjords of southeast and south central Alaska	Contrast recent glaciated landscapes to more stable and tidewater to non-estuaries; Compare tidewater glacial vs. nonglacial; Document substrates for habitat mapping; Detect species distributions; Determine some of physical and biological effects of deglaciation. They have complex oceanographic regimes and teasing out would be good.	**Scientific:** Intense fisheries issues; Marine Protected Areas establishment; Emerging landscapes that are often extremely dynamic; Lots of opportunities to leverage off of other studies in these areas; And lots of opportunities to have strong outreach component e.g. cruise ships; There are also recolonization issues, e.g. following biocatastrophe; Isostatic uplifting.

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: Alaska Caribbean West Coast Great Lakes Hawaii Atlantic North	Submarine Seamounts, ridges and associated unknown biological hot spots; Knowledge of impact of Seamounts on ocean dynamics; Also other abrupt topography; North/South Ridges in heterogeneous Lake Superior;	Document evolution of seamounts, circulation, and currents.; Document ecosystems esp. in the deep water. survey triage of hot spots; different tactics for each hot spot; discover; inventory biota; explore; Identify processes; find new species, distribution of sediment & benthic communities, distribution of fish, influence of bottom currents, and deep seamount biomass; amounts; Conduct altimetry mapping comparisons; Geoid products; map, and ground truth. Sample and take direct observations with moored stations & deep dives; verifying location; measure deep scattering layer over hydro plumes	**Scientific:** Not documented or known well; Fundamental dynamics needed for understanding role as biogeographic "stepping stones"; Unique ecosystems; centers of upwelling; unique species; unique trophic systems and food webs; Discovering of biodiversity, potential conservation areas; Explains maritime geologic history; New species, dispersal, and evolution, biogeography, new habitats; Pacific plate evolution; topological / biological coupling; foraging, upwelling; fish migrations; Record of climate change in deep Corals; **Industry:** commercial fisheries, minerals, biotechnology; **Outreach:** Public interest, lots of opportunity
Ecosystem - Abrupt Topography	Region: Alaska Caribbean	Trenches: Aleutian Trench; Impacts of Underwater topography (Sea mounts, pinnacles, reef edges); Caribbean trenches	Inventory and document geology (improved mapping) and habitats esp. corals and methane seeps, document these trophic systems; Identify new species; ID hot spots of biological diversity; Caribbean: Exploration in trench region to understand the interactions between abyssal depths and shelf waters (including abiotic/biotic constituents)	**Scientific:** Possible feeding dynamics; possible resources in shallow areas; deep water coral communities for fish habitat; major subduction zone that is unexplored; Baroclinic effects; nutrient production; biological productivity; Unexplored; Identify geothermal activity; understand dynamics of nephaloid layer; **Outreach:** excite the public - "new frontier"; identify new organisms; biotech development; identify areas of research; **Industry:** deep water impact of fisheries habitats; cultural and historical data

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: Caribbean	Understanding the ecology and oceanography of Florida Straits	Examine source water currents, pollutants, nutrients, and plankton	**Scientific:** Identify target areas for research; Identify pollutants and their sources/transport (ex. HABs); Identify new fisheries; **Industry:** Identify linkages between fisheries (including sources, sinks); management knowledge and resources; **Outreach:** ecotourism; feasibility of energy conservation
Ecosystem - Abrupt Topography	Region: Gulf of Mexico Alaska Caribbean Atlantic North Atlantic South West Coast	Topographic areas with biological communities	Time observation of topographic areas; revisiting topographic features that have significant biological communities; change in bathymetry; time lapse data	**Scientific:** access fish stocks; assessing changes in habitat and populations; species composition; **Industry:** resource management
Ecosystem - Abrupt Topography	Region: Gulf of Mexico	Lithoherms	Map; identify and characterize; geology	**Scientific:** Lithotherms not studied; may find deep corals on them; unexpected discoveries
Ecosystem - Abrupt Topography	Region: Gulf of Mexico	Cayman Trough	Mapping; plume prospecting; inventory and characterize; Identify deep corals	**Scientific:** significant potential for hydrothermal activity at the Cayman trough (active spreading center) and not mapped; can do it in a short amount of time
Ecosystem - Abrupt Topography	Region: North Atlantic	Gravel Cobble Bottom - continuous features vs. discrete; Gravel Windows - sediment disturbed & gravel exposed and not well documented	Not well documented	**Scientific:** Not well documented

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Abrupt Topography	Region: West Coast Alaska Caribbean Atlantic North Atlantic South Hawaii Gulf of Mexico	Banks; Fracture Zones; Subduction Zones; Canyons; Sea Mounts	Mapping; subsurface information; subbottom profiling; biosampling; currents; temperature; chemical description; cores to sample the microbial activity	**Scientific:** untouched communities to understand equilibrium before disruption; trying to understand how they evolved thru time (e.g. transient?; duration of settlement in any one spot.) unique species w/ biochemical properties; assessing connectedness among and between; genetic fingerprinting of some of the species; effects of exploitation
Ecosystem - Banks & Basins	Region: Atlantic North Atlantic South Caribbean Hawaii	Bahama Banks and deep basins	Survey and map; Explore mechanisms behind whiting events; sea level studies; geology; karst studies; low standing reefs; archeology - shipwrecks; reef studies; coral bleaching; carbonate production; reef sampling/coring for sea level and paleoclimate studies; ID highly migratory species and organisms; fisheries oceanography; many habitats to observe different regions; using ships, satellites; satellite based; remote sensing; satellite telemetry; critter behavior; sea level data; sediment traps; water column sampling; Document biogeography and taxonomy; Document physical, chemical, geological, and sediment characteristics	**Scientific:** Unexplored regions; new knowledge, increased understanding of climate/sea level change, see 'why'; Whiting events unknown - Calcium Carbonate in water column; lots of interesting geology; shipwrecks; goes to great depths over short distances - basic exploration; carbonate bank evolution; fisheries - provides connectivity to rest of Caribbean; general coral reef health; **Industry:** fishery; Biotechnology; **Outreach:** great opportunities; public interest; recreation; tourism; education; **Regulatory:** fishery
Ecosystem - Basins & Banks	Region: Hawaii	Solution Basins	survey, map, ground truthing, sampling, direct observations, ID and characterize organisms as well as features	Scientific -history of HI, ID new species, species dispersal, evolution, biogeography, ID new habitats; Industry - fisheries, minerals, biotechnology; Outreach -public interest, lots of opportunity

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Basins & Banks	Region: North Atlantic	Glacial Scoured Areas Channels	Not well documented	**Scientific:** Not well documented
Ecosystem - Caves	Region: Caribbean	Biodiversity and ecology knowledge of marine caves	Characterize and Identify biota using molecular genetics; Map; Determine chemical, geological, biochemical, and physical characterization, geology, Examine for archeological significance	**Scientific:** New and relatively unstudied ecosystems; Would identify new species and higher taxa; living fossils; most species endemic; potential for new life forms; potential links for deep sea; biogeography; evolutionary questions; genetic diversity
Ecosystem - Extreme Environment - Sea Ice	Region: Alaska	Characterize and explore Sea Ice areas and the Marginal Ice Zone; Wintertime trophic food web; Need long term Ice Dynamics; Info on sediment records; Map of sea ice coverage and rates of change.	Characterize and explore high salinity and low temp (cryosphere) environments; Map all oceanography features and content. Identify and catalogue the trophic webs and migration patterns that support birds and mammals in the wintertime; look at what physical processes impact their system; what zooplankton are available for species dependent on their food type; document water column biology (zooplankton); Document physical processes; Ballena studies; Increased fetch (expanded open ocean). Identify the role of sea ice cover in structuring the marine ecosystem; how does this vary with latitude; Systematic ice coverage surveys.	**Scientific:** Completely unknown and potentially Biotically important. Identify new species and novel protection mechanisms against extreme conditions; Many birds and mammals spend winter in Bering and Aleutians, but little is known about what they eat there; Better understand food web dynamics; Identify changes in ice distribution for climate response issues; Bering Sea is in an ecosystem crises; sea ice is believed to play a critical role for production of shelf ecosystems; predicted to diminish; Unknown balance of physical and biological processes associated with ice dynamics; **Regulatory:** Supports the Endangered Species Act. **Outreach:** Bering Sea Ice areas are cultural assets

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Extreme Environment- Vents, Seeps, and Volcanoes	Region: Caribbean Atlantic South Gulf of Mexico Hawaii	Find new vents and seeps (includes fresh water seeps), Need maps of content and locations; Montserrat in Gulf of Mexico; Hydrates and cold seeps/vents; sediment flows and biota; discover and document unknown active volcanism	Survey and document biogeography and taxonomy and discover new species and processes; Document physical, chemical, geological, and sediment characteristics; Map dead and living muscle & clam communities associated with seeps; Compare with subsurface; Understand the differences in communities between Blake Ridge and Gulf of Mexico; Document hydrothermal activity; Understanding the relationship between hydrates and cold seeps/vents and between sediment flows and biota (including microbes) and brine pools; discover new species and processes;	**Scientific:** - Unknown areas; similar to marine caves and all taxa biodiversity inventory lists; unknown exotic organisms; new insight into the evolution of life; every vent appears to be a bit different; Key to understanding active Volcanoes; **Industry:** also same but commercial benefits are less; Key to understanding the different impacts on habitats

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Extreme Environments - Vents, Seeps, & Volcanoes	Region: Gulf of Mexico West Coast Hawaii Atlantic North Atlantic South	Unknown chemosynthetic communities (subsurface - down several km); Microinvertebrate assessments; hydrate vents, seeps and vent communities	(Subsurface - down several km): oil seeps and vent communities; Inventory and characterize; isolated ridge system; new biota; larger geographic context; subsurface 3-D seismic surveys; biogeography (sample); locate plumes; Explore why communities exist; what turns these areas on and off?; Identify and characterize areas by Neuston tows; Microinvertebrate assessments e.g. kelp forest assemblages and soft habitat; microbial ocean; assemblages; interactions; predator/prey relationship	**Scientific:** very little info on distribution; gas chemistry (plumbing system); key biogeographic province for global hydrothermal geography; unknown regions; new biota; Provides new knowledge of significant communities through evolutionary time; global importance; genetic links between regions; **Industry:** may promote restrictions; resource management; biotech; may be unique with amount of oil naturally occurring in Gulf; biotech applications; pharmacological applications; gains (includes safety) in ocean management; fishing, potential new bioengineering products; serve as areas of production "oases"; ocean resource management (ex. protection of the communities); **Outreach:** Unusual topic for media; education. **Regulatory:** Homeland Security

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Extreme Environments - Vents, Seeps, Volcanoes, Trenches and Arcs and General Ecosystem initiatives	Region: West Coast Hawaii	Lack of microbial information at seeps; Understand formation of biofilm/microbial mat in extreme environments; Understand the Pacific Ocean regarding the origin of life (vent communities, any optimal environments, etc) Gaps in exploration in past of arcs and trenches	Insitu sampling (currents) and genomic identification & chem; particle counter for small particles - size fractions; Microbial assemblages; characterization and mapping ; taxonomy; role they're playing in larger ecology; bio/geo/chemical processes; bioactive compounds; subbottom profiling, coring. Consortia for development; Measurements of interaction between geology, biota, circulation area to target (Tow-Yos - sampling in vertical) Tonga Trench; deep dive mapping of gas hydrates; Standard plume techniques at Tonga Kermadec; location of chemical fluxes; biota; volumetrics; geologic signatures; sensing water column	**Scientific:** huge opportunity for fundamental discovery; Plate tectonics; Subduction factory; Tonga Kermadec; less than 2% been explored; mineral resources; bioactive compounds; health in the coastal zone; biotechnology; human health; (e.g. blooms); cause-effect; pollutants (tracking); **Industry:** seafood; biotech; genome mapping and modes of life, discovery of new antibiotics, invasive species; human health; biotoxins; untouched communities to understand equilibrium before disruption; trying to understand how they evolved thru time (e.g. duration of settlement in any one spot.); unique species w/ biochemical properties; effects of exploitation **Outreach:** origin of life; challenge for outreach; conceptual more than visual; education **Regulatory:** counteracting bioterrorism;
Ecosystem - Karst / Ring Depressions	Region: Great Lakes	Karst Features in Lake Huron (sinkholes); Ring Depressions (400-500 m across; 20-30m deep);	Collect info on spatial coverage, depth, dimensions, biology, chemistry, local flow pattern; How they formed, influence on distribution of benthic communities, sediments, contaminants, why not in other lakes	**Scientific:** Potential source of groundwater input, fish habitat, prehistoric culture; Most widespread feature on floor of North America's largest lake

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Lakes	Region: Great Lakes	Lake Biodiversity; Need to recharge all of the component areas of the lake systems;	Bio / Geo / chemical processes; Community structures & compositions; Species Diversity - looking for new species; (3 African Great Lakes); Rapid Assessment survey; Collection of long term Sediment cores; Geo-thermal Vents Systems; Describe landscape census; Looking for midwater scatters; Multibeam survey; Physical Ocean Sampling; Natural History Survey; Investigate use of streams for spawning; Ecosystems approach to water quality; Examine revival of species, Pollutants	**Scientific:** Undiscovered areas of bottom; findings new species in Great Lakes Understanding the origin of species and of Great lakes; River run-off; linkages between estuaries and river fauna, biota; complexity issues unique to the freshwater Lakes systems we drink. **Industry:** Global Pressures on fresh water resources; Global issues and local pressures on fresh water resources; New Species; Bio-Technology; Pharmaceuticals; Fundamental Ecological Principles to Apply to Management; **Outreach:** Human connection to Water Resources; Public Health Regulations: Land use polices and water sheds;
Ecosystem - Shorelines to Ledges	Region: Atlantic South Gulf of Mexico Alaska West Coast	The Point region: why is it so productive? Shoreline erosion; Intertidal zone; Inner shelf; Ledges, West Coast continental shelf	Not well documented; Map and inventory areas; ID subsidence in LA; Gulf of Mexico; erosion rates; sedimentation; storm surge impacts; salt water intrusion; habitat distribution and loss; impact; invasive species; impacts on infrastructure; Document biodiversity and taxonomy; Identify and characterize potential fish habitats, ID ground water discharge, relationships between biology and geology; physical oceanography - water mass characteristics; invasive species; harmful algal blooms Document archeology; Benthics; baseline mapping (high resolution); habitat substrate; cables physical oceanography;	**Scientific:** Not documented; Remote nature (Alaska); Will add value to other studies; unique - meeting of three water currents (The Point); very productive; hurricane impact - coastal hazards such as erosion, rapid response to natural or man-made catastrophic events, paleoshorelines - coastal evolution; knowledge of substrate, benthos, habitats and relationships; **Industry:** huge potential for natural gas economics; sand and mineral resources; understanding fish habitats for Fisheries; biotechnology **Outreach:** public concern; "backyard" education; entire community, **Regulatory:** protection from storm surge; loss of wetlands and other habitats; Conservation: sustainability; rational decision; biggest info gap

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Shorelines to Ledges	Region: Caribbean Atlantic South West Coast	Knowledge of fisheries habitats; What are fish stocks and habitat on the Islamorada Hump (nominated as a MPA)? Connectivity of habitats on shelf and edge of shelf; trophodynamic study.	Collect information on distribution, taxonomy, abundance, condition, and diversity, determine productivity in reef systems, define critical path and corridors including eddies and bio-physical connections; Identify key areas that may need protection - "critical habitats"; due to Insufficient scale/depth; define critical path and corridors including eddies and bio-physical connections. ID connected habitats; extent of spawning areas; connection between reefs; sample; determine source; track history of fish; follow biologics to determine behavior; tagging studies; molecular data analysis.	**Scientific:** Classically important fishing areas; never been explored; Marine Protected Areas location & defining; functionality of MPAs; understanding of unknown - ecological systems; behaviors; understanding of energy flow; status/impact assessment; **Industry:** Ecotourism, recreation; **Regulatory:** Fisheries Management; Better ability to monitor impact of fishing and other disturbances for areas of protection; Target areas for research;
Ecosystem - Shorelines to Ledges	Region: Gulf of Mexico Atlantic North	Mississippi River outflow on habitats; Knowledge of near shore environments	Understand the impacts of Mississippi River outflow on habitats; ecosystems (and secondary fresh water input); Determine river influence on Gulf systems; bio/geo/chem; frontal zones; Inventory, characterize, and measure: habitats, bathymetry, Bio/Geo/Chem of shallow water processes near fronts - colds corals, Archeology of Biological / Geological / Chemical characteristics.	**Scientific:** bottom health; flux of nutrients; **Outreach:** public interest; science; education; **Regulatory:** coastal zone management; fisheries management; conservation; policy remediation; regulatory oversight of runoff quality;

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Shorelines to Ledges	Region: West Coast	Near shore habitat; Archeological paleoclimate area	Habitat on near shore (shelf and slope); Archeological paleoclimate area; targeted anthropogenic impacts; high definition visual surveys; look for arch. sites of previous civilization; look for deeper wrecks; understanding of flows of chemicals; ID fisheries; physical; current flow interactions; discover history influences; understanding margin marine boundary layer	**Scientific:** understand part of ocean directly most interact with & human impact; link of chemistry and biota; **Outreach:** reach new stakeholders; connection to public; **Regulatory:** conservation areas.
Ecosystem - Slopes	Region: Alaska Atlantic North	Continental Rise and the Outer Continental Shelf, right down to the Abyssal Floor Plain; Slopes (600 to 4000 ft); Study Transitional Areas Between Biogeographic Areas & deeper Shelf Slope Regions	Document biological communities and geologic history, Examine record of continental climate; Species distribution and ranges; species dynamics, tropic interaction, invasive, patterns; Not Documented	**Scientific:** Least studied part of the ocean; a place where the bigger tsunamis may be generated from slope edge slumps; Not Documented; Very little information available that is not broad scaled; what regulates them?

Category	Workshop	Exploration Targets	Description	Benefits
Ecosystem - Slopes	Region: Atlantic South Alaska	Shelf to slope transition area; complex habitats - reefs (outer shelf), deep coral banks,	Survey bottom; physical sampling of water column dynamics; biological survey; sampling structural data; describing wreck structure; wood samples from wrecks; corrosion analysis; sampling substrates, subsurface geology; site stabilization; covering and uncovering of wrecks; observe new species; species interactions/behavior; habitat utilization; network of sensors; multidiscipline surveys; fisheries; ID community structures; characterize content of entire water column; plan comprehensive multiyear surveys (expand MARMAP monitoring, NMFS); generate timeline	**Scientific:** New knowledge, better understanding; impact assessment; gas chemistry; ID new species; impact of cable laying; lack of knowledge of biodiversity; pharmaceutical interest (sponge communities) **Industry:** resource management; oil industry; **Outreach:** historical / educational use; **Regulatory:** industry - protection
Ecosystem - Slopes	Region Atlantic South	Explore shelf break - upper slope	Broad based exploration survey; ID intercomparisons; use moored arrays; satellite; airborne; LIDAR; drifters; Include shelf edge; reefs; hard bottoms; paleoshorelines; spawning locations and sediment traps; habitat based observation; turbidity transport; mineral exploration; gas and groundwater seeps; dedicated estuarine coastal vessel for education and training of next generation of oceanographers to establish program of data and sample collection - potentially re-outfit Ferrell for this purpose	**Scientific:** observation studies; baseline characterization of very productive areas for EFH; upwelling zones; potential for mass wasting; tsunami generation; chemosynthetic communities; fluid flow; evolution of continental margin; mapping low stand deposits; influence of Gulf Stream; **Industry:** recreational; fishery; tourism; **Outreach:** get students out to sea - lots of opportunities; relevant region - in our back yard; **Regulatory:** coastal erosion; fishery; MPA's; regulation of shipwrecks

Category	Workshop	Exploration Targets	Description	Benefits
Episodic Events	Region: Great Lakes Atlantic North Atlantic South Caribbean	Integration of discoveries with accountability, need basic research with applied science; Event driven Storms, Surface and Benthic storms; Blooms; Distribution of nutrients, biomass & current influences; Rare species events	Identify distribution of nutrients, biomass & current influences; Identify frequency, strength, intensity, impact, magnitude, compare & contrast	**Scientific:** Understanding coastal processes; synergy of impacts and mitigation; **Regulatory:** Important for costal zone management; **Industry:** Social economic relevance; safety of life and property;
Episodic Events	Region: Gulf of Mexico	Hypoxia phenomenon; Loop and related currents to HAB formation	Origin; effects of hypoxia; Understanding of relationship of loop and related currents to HAB formation and other species that are not normally seen; discover mechanisms of transport that leads to formation and distribution	**Industry:** economics; recreation industry; impact industry (shrimp; oyster; and fishing); **Outreach:** human health issue
Episodic Events	Region: West Coast	Plate scale to mesoscale	Develop a Plate scale to mesoscale (gyre scale) observatory for long-term understanding of episodic events; measure absorption of CO2; requires a thorough mapping effort; collaborative effort; provides new ways to do oceanography; understanding fluid flux productivity of subduction zones; sources of interplanetary life	**Scientific:** supports a scientific CNN; opens temporal domain; resolves limitations of surface vessels; new paradigm of sampling in time and space; **Outreach:** interactive telescope into inner space; internationally unique

Category	Workshop	Exploration Targets	Description	Benefits
Extreme Environments - Vents, Seeps & Volcanoes (See also: Ecosystem - Extreme environments - Vents, Seeps, and Volcanoes)	Region: Great Lakes Hawaii Caribbean	Unknown hydrothermal features in lake systems; Need high resolution spatial & temporal zooplankton measurements over space & time; classification needed; Unknown Seeps/ Non-Oxygen Environments - evolution in isolation, inter-lake comparisons, genetics in large time scales Active volcanism; Sample and map new hot spots; fundamental understanding; Unknown knowledge of micro-organisms in the deep sub-bottom	ID chemistry, microbiology, nutrient dynamics from high resolution surveys. General mapping; access naval data; Airborne geochemical, seismic; and passive acoustics measurements; track plumes and trace elements from plumes from air; set up listening arrays; locate features using mapping technology; Investigate Loihi, Samoa, Louisville Ridge; sampling deep mantle plume; sample volcanic edifice edge of seafloor; seafloor biosphere needed.	**Scientific:** Unique and unknown evolutionary aspects of microbiology in fresh water lakes, bioremediation; Major component of the food web depends on fresh water body; Fundamentals of evolution of life, island biogeography; extremophiles, Identify sites and new life in sustaining processes- possible origin of life answers, composition, geological properties, biological properties, chemical properties and flux, plume characteristics **Industry:** oceanographic power source for sensors; minerals and biotech; **Outreach:** Lots of public interest, education and conservation.
Geology & Geomorphology	Region: Alaska	Glaciers: origin in Bering Sea; Discover characteristics of environment created or released form glaciers; Plate Boundary - Strike Slip System; Documenting climate variability	Identify and characterize these environments, explore, collect and measure features; Map and perform water column survey, identify and characterize biota; Neotectonics; Areas of seeps; compare w/ other plate boundaries; Areas of large earthquakes and sediment slides; 500 million year record of global climate; Need to examine it to look for variability	**Scientific:** Not well understood; fresh water inputs to ocean; consequences of rapid glacier retreat; Not well documented; Is human activity changing the Gulf of Alaska; **Industry:** Possible coldwater petroleum seeps

Category	Workshop	Exploration Targets	Description	Benefits
Geology & Geomorphology	Region: Atlantic North Atlantic South Caribbean Hawaii	Discover and mapping of paleoshorelines and relict reefs (tend to be fish habitats); Lack of sub-bottom mapping of sea floor sediments Holocene (last 10,000 yrs) Not well documented; Knowledge of Physical Processes related to geomorphology	Map; ID; characterize shorelines and reefs; develop baselines for geology, biology, water quality; ID and characterize sediments; ID historical sea level information, find wave notches, ledges, other geomorphological features, lava tubes and marine caves; ID mass-gravity movement, turbidity flows, hydrate beds, slope instability; conduct chemical analysis	**Scientific:** understand sea level and paleoclimate changes, essential to understanding history; foundation for essential fish habitat, sea floor habitats, beach deposits, and anthroprogenic factors. Understand canyon formation processes, safety (geo-hazards) habitats, Not well documented
Geology & Geomorphology	Region: Gulf of Mexico	Bottom boundary dynamics; Knowledge of sub-bottom characteristics; Knowledge of rivers of warm; dense brine from salt province; Knowledge of slope stability	ID and map distribution and process details of fluid and gas expulsions; carbonate formations; and seismic activity; Determine morphology; composition; dynamics; Heat flow measurements; mapping; origin; effects; Inventory and characterize debris floats; gas; slopes; faults; gas hydrates; mud flows; date features	**Scientific:** tipper for hydrocarbons (energy resources); fish habitat; geohazards; climate/carbon cycle; ID chemosynthetic communities and controls on the fluid and gas expulsion; modifications on habitats; **Industry:** resource management; identifier of hydrate deposits and industry zones; Origin and effects of the Gulf salt province; Oil and gas exploration and production.
Geology & Geomorphology	Region: Gulf of Mexico Great Lakes	Knowledge of Mega-furrows	Determine origin; physical characterization over time; size; shape; currents	**Scientific:** recently identified in Gulf; impact on currents; don't know where sediment goes from erosion; habitat issues

Category	Workshop	Exploration Targets	Description	Benefits
High Resolution Bathymetry	Region: Alaska Great lakes Hawaii	Not mapped; not enough resolution in existing maps; Complete Bottom survey of Great Lakes not done - Shallow water mapping; Extension of Coastal Estuaries & Wetlands; Understanding substrates to particle size; Near shore fossil coral reefs (Chicago and similar environments); east-end of Lake Superior; Mid-Lake Reefs; Mid-Lake ridge through Lake Huron; Lake Champlain; Foundation for exploration; Need more accurate charts of Pacific seamounts and banks.	Conduct high resolution hydrographic, bathymetric and tidal data survey - mean low and high water with multibeam and side scan sonar; Document navigation hazards, and biota	**Scientific:** Not mapped; not enough resolution in existing maps; Tidal data to establish boundaries; Understand how sea data changes with events; Unknown biota; Discover new features and location; Fisheries; Cultural Heritage (Climate history, Lake Levels, drown stream mouths & Inundated cultures); Identifying Exploration Targets; Road maps for research; Inferring Lake processes boundary conditions; insight into deep water circulation & sedimentation patterns; **Industry:** Arctic path for shipping; Navigation
High Resolution Bathymetry	Region: Gulf of Mexico	Mapping of the Gulf, Need framework for further exploration and research; Mapping between known topographic features	Bathymetry surveys with multibeam and side scan sonar	**Scientific:** Unknown regions: utility of dataset once it is developed; not done in many areas; slope is an important habitat; use bathymetry to find essential fish habitat (seasonality); **Industry:** new discoveries; interactive website; discovery of new resources (fishery; bioproducts; chemical; oil); **Outreach:** education - tapping into grad students; incorporate data sets into curricula such as GIS classes

Category	Workshop	Exploration Targets	Description	Benefits
Human Impacts	Region: Alaska Gulf of Mexico Hawaii	Identify Hazard Dumps at sea; Potential threat site location; Need safe nuclear waste disposal site.	Location of site of potential threat to the environment and processes near the sites; wrecks; marine debris; dump sites; abandoned platforms; Determine location and chemistry of material; Characterize these sites	**Scientific:** knowledge of impact of materials on ecosystems health; **Outreach:** much public interest; **Industry:** Potential biohazard, fisheries; **Regulatory:** conservation; management; safety; remediation; policy; regulation; enforcement; pollution impact; long-term anthropogenic impacts; safety
Human Impacts	Region: Caribbean Hawaii Atlantic North	Impacts of Pollution; Pollution and marine pathogens; Understanding biomagnification of pollutants and toxins in the marine food web (similar to large pelagic); Knowledge of impact of Fishing on Ocean Regions	Determine anthropogenic impacts on marine mammals and their habitats from ships, blast fishing, Military Ops, Energy Refineries and energy conversion activities; broad area surveys, tracking mammals; Use pathogen count as a marker; quantifying toxins;	**Scientific:** may resolve competition for resources and habitat loss and degradation; understanding impact on ecosystems; fishing; Archeological Impacts; History of technology; **Outreach:** Health and education; **Regulatory:** MMPA, EPA dumping at sea management; Health of Benthic Habitat; CoML; Fisheries management; unknown areas of deep benthic fish populations.
Human Impacts	Region: Gulf of Mexico	Anthropogenic noise	Monitoring natural (biological and geological) and anthropogenic noise; effects of human induced noises on biota; natural noise	**Scientific:** natural noise can be used as a measurement of health - can be used as a proxy for measurement of animal health

Category	Workshop	Exploration Targets	Description	Benefits
Marine Conservation	Region: Alaska Atlantic South	Essential Fish Habitat; Need knowledge of Recruitment and spillover mechanisms in Marine Protected Area networks; Characterize "deep" Marine Protected Areas (including deep reefs)	Map and inventory benthic habitats to gain understanding impacts of essential fish habitats; candidate areas of protection; Map; ID; characterize; develop baselines for geology, biology, water quality; oceanographic parameters; need to explore and ID ecologically, info on spawning, eggs, larvae spillover and transport systems etc.; behavior of early life history stages that affect recruitment. ID candidate Marine Protected Areas; Location & dynamics of archeological sites of historical significance through the use of: vessel explorations; data mining; manned observatory; fixed sensors and arrays; ID biota that needs protection	**Scientific:** little is known about proposed marine reserve regions - most are deep regions, greater than 50m; Understand role in supporting ecosystem spawning **Regulatory:** huge management implications; conservation; info for enforcement; ensure knowledge of the constituents that need protection; management and policy **Outreach:** SAFMC (South Atlantic Fishery Management Council) purposes; determining potential recreational interests; public affinity; **Industry:** Possible biotech implications
Marine Conservation	Region: Atlantic South	Oculina Banks; Effect of closure and 10 yr limit on no fishing;	ID; characterize recruitment and spillover mechanisms; artificial reef impact; comparison with existing baseline studies	**Scientific:** only Marine Protected Area in S. Atlantic Bight where fishing is not allowed, huge oculina coral region, deep reef at 300ft, oculina destroyed by shrimp trawling and scallop dredging, efforts to reseed right now, will coral self recruit?, unique habitat, assessment of restoration techniques, still don't know a lot about it, no research funds provided to demonstrate effectiveness of Marine Protected Area in restoring corals and fishes

Category	Workshop	Exploration Targets	Description	Benefits
Marine Microorganisms	Region: Alaska Atlantic South Caribbean Hawaii	Knowledge of Microbes in the Bering and Chukchi Sea and other seas; Microscopic Interfaces; Microbial roles in ecosystems; They are the most abundant organisms in the marine environment; control biogeochemical cycling;	Microbiology and micro-zooplankton sampling of abundant and important microbes and micro-zooplankton; Explore unknown micro- / nano-environment; Characterize it including Information on microscopic interfaces of chemistry, microbiology (liquid-solid interface)	**Scientific:** Gain knowledge of ecosystem health; Understand long-term variability. Not well understood; Need fine-scale knowledge; These organisms likely play critical role in function of ecosystem; Understand changes affecting ocean productivity; Understand role in producing biocompounds and enhancing biodiversity; **Industry:** Impact on Ecosystems and human & habitat health; biotech applications
Marine Microorganisms	Region: Hawaii	Marine parasite lifecycles; Marine viruses	Documenting parasites; life cycle; primary and secondary hosts	**Scientific:** Knowledge of the effects on carbon and phosphorus cycling.
Marine Organisms	Region: Alaska Caribbean Great Lakes Gulf of Mexico Atlantic North	Migration patterns for high latitude organisms; How Animals use Vision & Light to Orient Themselves in the Water; Populations in flux; Biological Transitions Zones; Understand exotic invasive species; Understand cross Gulf migratory birds; Distribution migration & abundance of Gelatinous plankton	Collect data to understand the vulnerability of birds and mammals; document visible communication; Linkages of rivers estuaries and basin; Use of streams for spawning; Ecosystems approach to water quality; Examine revival of species, Pollutants; Identify organisms transitions zones; mapping of systems; Understand invasive species success or decline, impact, taxonomy, and genetics; Contribute to migratory birds database (can add bird migration to other studies)	**Scientific:** Support for designation of critical habitats; Know very little, spin-off potential for other technologies, dictate habitat utilization, mating; helps identify global climate changes, fish species mobility, numbers; Ranges decline of organisms; Changes in biodiversity; ecological impacts; Pelagic plankton are the dominant Biomass; Fisheries Impact, Evolution Knowledge; **Outreach:** education effort; **Industry:** economics; resource management

Category	Workshop	Exploration Targets	Description	Benefits
Marine Organisms	Region: Atlantic South Great lakes Hawaii	FISH: Expanding fisheries (exploitation of new species), Distribution of marine geographic endemics; Abyssal Fish (> 50m); Evolutionary Biology; evolution in isolation, inter-lake comparisons, genetics in large time scales; Genetic connectivity of Gulf of Mexico ecosystems; Understand specimen migrations through Hawaii Arch.	Establish fishery dependent sampling & fishery independent sampling baseline information such as abundance, growth rates, reproduction, etc.; getting samples from landings reproduction, etc.; conduct independent surveys; Targeted tagging and photo ID; Otolith elemental fingerprinting Document taxonomy and life history; Many of the best studied groups have pelagic larval distributions - corals, shallow-water tropical marine fishes; may give much better understanding of evolution and extinction. impact of invasive species, spawning (where & how especially in winter season), character displacement behavior; genomic mapping	**Scientific:** Management of newly exploited species; new pharmaceutical compounds such as antibiotics; Know very little, gene flow problem, recruitment problem, invasive species problems, displacement behavior; knowing mating game, life history, learning more about diporeia decline; island biogeography; Recruitment patterns; larval dispersal, distribution, and stages; Characterizing reefs; **Industry:** sustainable fisheries; bioprospecting **Outreach:** great educational opportunities; power plants (e.g. zebra mussel issue), municipal water plants, carbon cycling; huge public concern; stewardship of fisheries; **Regulatory:** sustainable fisheries; water quality and contaminants; marine bioconservation
Marine Organisms	Region: Atlantic South Caribbean Great Lakes	Productivity Knowledge: Seasonality of upwelling and associated spawning and larval distribution; Habitats of spawning aggregations of fish; Connection of separated populations (esp. fish)	Map locations of upwelling and gyres; measure productivity; sample plankton; measure vertical flux to sea floor; physical/chemical water column characteristics; Document distribution, taxonomy, condition, and life history; determine mechanisms underlying Fish aggregations; How Habitats impact each other.	**Scientific:** to understand importance of upwelling, explain or predict recruitment to fisheries, effects on estuarine systems, life history; unique habitats and locations; larval transport pathways; understanding of dynamics of fisheries and ecosystems; **Regulatory:** many areas over fished; conservation and management

Category	Workshop	Exploration Targets	Description	Benefits
Marine Organisms	Region: Caribbean Gulf of Mexico Hawaii West Coast	Marine Mammals: Distribution movement, orientation, and abundance of Deep Diving and Long Range Marine Mammals; Food source/distribution linkage (includes vertical migrates); migration patterns; understand habitats of large pelagic animals; Identify Coelacanth, giant squid, megamouth (obscure, unknown animals) ID the guideposts in the ocean. ID how populations succeed; behavior patterns; interactions with ocean structures; use of habitat; range and navigation	Observe visual behavior, environment, and habitat through use of all senses; Collect and document the understanding distribution and migration patterns of marine mammals; Charismatic megafauna (whales; manta rays; sea turtles; dolphins; whale sharks; etc); response to anthropogenic impacts (noise; other pollution); location; reproduction; general life history questions; genetics; Collect images; Tagging and satellite data comparisons for behavior patterns; acoustic subsurface surveys (foraging) by attaching instruments to animal movements; interaction with benthos, linking foraging with physical environment	**Scientific:** Discover new species; Unknown distributions; global entities and don't know much about them; reproduction; genetics; bioactive compounds; understanding role of compounds in nature; **Industry:** resource management; bioproducts; public disclosure of data; **Outreach:** fascinating to public; huge outreach component; education **Regulatory:** Conservation and management; some species are endangered; conservation; International policy cooperation.
Marine Organisms	Region: Caribbean Hawaii Atlantic North	All taxa biodiversity inventory; Marine biodiversity - inventory from Hawaii Islands - Deep Marine (>200m - ~6500m or beyond); Ecosystem Engineers and foundation species (corals, tile fish), Knowledge of novel feeding relationships	Species inventory; Identify chemical characteristics, abundance, and diversity; Discover and inventory new living resources (non-fishery) with commercial potential, target areas and habitats not well documented; coordinated Hawaiian Island. Ridge inventory; establish patterns;	**Scientific:** Preservation of species; Discover new species; survivability and genetic and chemical diversity; bioactive compounds, new bioproducts; understanding role of compounds in nature; census of marine life; Unknown feeding relationships could be major sources of nutrition; discover new linkages; Industry - bioproducts; public disclosure of data; **Outreach:** media coverage; understanding wide environments; **Regulatory:** management.

Category	Workshop	Exploration Targets	Description	Benefits
Ocean Resources - Bioprospecting	Region: Atlantic North Atlantic South Caribbean	Discover potential Bioprospecting targets	Charleston Bump (mg); Blake Plateau (gas hydrates; sand); inner shelf; collect samples of marine organisms; water samples; sediment samples; collect DNA from marine organisms; ID application of new micro/macro organisms on drug discoveries & other industrial products;	**Scientific:** new information; resource identification; oceanographic processes; **Industry:** tourism; recreation; New industrial processes and biotech products; **Outreach:** conservation of resources; **Regulatory:** local governments; coastal zone managers
Ocean Resources - Energy & Minerals	Region: Alaska Atlantic North Atlantic South Gulf of Mexico Hawaii West Coast	Knowledge of ocean renewable resources: Gas Hydrates and provinces, minerals deposits; Discovery of deep sea minerals; Develop detailed baseline knowledge of candidate currents/locations; crustal processes	Document interaction w/ ocean; Identify and characterize communities associated with them; Survey, Map distribution and location. Charleston Bump (mg); Blake Plateau (gas hydrates, sand); inner shelf; manganese nodules; phosphorites; sand resources for beach nourishment; heavy metals; Crustal processes that affect fluid flow; determination of location and volume of hydrate resources; classification; chemistry; fluid flow; subduction zone; hydrothermal processes; microbial populations and dynamics ID classification, fluid flow, and chemistry; ID climate impacts, slope stability	**Scientific:** undiscovered energy and minerals; impact on environment (climate; carbon cycle); geohazard/sea floor stability; means by which earth cools itself; how fluids are forced from crust; Global climate impact, **Industry:** potential natural resource; cable laying process; Methane deposits are two orders or more (is it recoverable?) than elsewhere in the world; more methane than other fossil fuels; tourism, recreation; **Outreach:** conservation; safety- Tsunami awareness and bottom mounted cables; **Regulatory:** local governments; coastal zone managers, shoreline protection

Category	Workshop	Exploration Targets	Description	Benefits
Pelagic Environment	Region: Atlantic North Atlantic South Gulf of Mexico Great Lakes West Coast	Mid Water Exploration: Knowledge of shelf-wide water column (physical, biological, chemical); Need constant monitoring of Pelagic community. Knowledge of "Life in one cubic meter of water" in surrounding waters; What is in the pelagic realm to conserve and exploit.	Characterization of organisms, circulation; nutrient distributions; nutrient flux; mixing; recruitment dynamics; jellyfish; conduct water column sampling; time-series monitoring; establish buoy networks, or an upward looking devices to monitor water column and seasonal change, transition rates, feeding rates etc.; collect ground truth data, compare between different biota. Characterize food web; link between upper water, slope water, and benthic water; how the midwater functions in this role; evolutionary relationships;	**Scientific:** Unknown interactions in the water column, "Largest Ecosystem and biomass on the planet"; knowledge of spawning and distribution patterns, baseline data for rapid response to blooms; new biota; micro level of how oceans work; Little known about larval distributions, taxonomy;. important to carbon cycle; lots of species unknown to science; unknown contribution to food web; relation with upper water community; link to climate change; discovery is guaranteed. **Industry:** HAB response; resources management; applications of tech.; **Outreach:** tourism, recreation, fishing, toxicology, pharmaceutical, biowarfare; public information via media. **Regulatory:** dumping regulations.
Pelagic Environments	Region: West Coast	Use of pelagic and benthic environments by economically/ecologically important species; by Rare Species	Life history; migration patterns; habitat; population; distribution and abundance; environmental properties; Track location of critter; Beacon to uniquely ID individual; Attach Critter Cam; fronts/eddies - use remote sensing to ID areas; Listen and observe sounds; LIDAR to monitor; observe; track fish	**Scientific:** basic knowledge of behavior; migrations and how they use their environment; resource management; little known about them; **Industry:** sport fishing; small business; they engender energy and excitement from public; **Regulatory:** need to know more to protect them
Pelagic Environment	Region: West Coast	Euphotic zone productivity, Harmful Algal Bloom (HAB) causes;	Collect data on HAB triggers, understand productivity of ocean in euphotic zone; understanding life stages of organisms; discover new members; <20 microns (includes viruses; parasites); spatial structures (scales); need balance equation	**Scientific:** HABs; understanding health of oceans

Category	Workshop	Exploration Targets	Description	Benefits
Sound in the Ocean	Region: Alaska Atlantic South Hawaii	Characterize and inventory naturally occurring sounds	Listen to seismic acoustics, fauna acoustics, Marine mammals, and fish; Use acoustics to determine migration paths	**Scientific:** New way to look at ocean; break into new applications of acoustics.

4.4 Partnerships

Integrated in the identification of exploration needs was an opportunity for the workshop participants list potential partners in exploration pursuits. It should be noted that the majority of the attendees represented academic and government stakeholders with less representation from commercial or other private organizations. As a result, the potential commercial partners identified during the workshops probably do not reflect the scope of potential partners who are likely to be engaged in the ocean exploration process.

Regional participants were given guidance in identifying partners including categories adapted from the *Frontier Report* in order to facilitate summarizing the overall regional results. The categories included government, academic, industry and non-governmental organizations (NGOs).

Participant recommendations for potential partners were divided into a set of "standard partners" and other need-specific partners. As discussed previously, the standard partners represented recurring organizations with a common interest in the region's exploration activities. These partners are listed at the beginning of each set of regional results in Section 3.4. Need-specific partners were identified based on their ability to provide unique support specific to the associated need. These partners are included within the contents of the regional results in Section 3.4.

Government agencies represented the largest category of potential partners. These partners represent agencies that assist in seeking knowledge about how the oceans function and to support their missions of national security, transportation, and the conservation and management of natural resources. Agencies recorded in the greatest frequency included NOAA and its components, NSF, Navy, Coast Guard, USGS, Mineral Management Service (MMS) and EPA. Foreign governments cited in order of highest frequency included: Canada, Japan, Russia, Mexico, Cuba, and France.

NGOs accounted for a quarter of the potential partnerships. These organizations are typically interested in a broad spectrum of ocean interests including conservation,

protection, education, entertainment, and research. Organizations frequently identified by the workshop participants include aquariums, museums (Smithsonian, Bishop), recreation groups and associations (fishing, diving and other local groups), and oceanographic entities such as the Harbor Branch Oceanographic Institution and the Woods Hole Oceanographic Institution.

Industry comprised a fifth of the potential partners recommended by the workshop participants. Industry sectors are expected to seek knowledge to support commercial activities such as fishing, energy and mineral extraction, pharmaceuticals; commercial fishing, energy (gas & oil) and biotechnology were identified.

Academic institutions concerned with oceanographic research were well represented in each region as potential partners. International universities were included for activities in the Bahamas and Canada.

A limited number of media organizations were specifically identified (e.g., the Discovery Channel and the British Broadcasting Company) but the participants recognized the media in general as important partners in exploration activities. These relationships are certain to expand with an increasing emphasis on ocean exploration outreach.

4.5 Issues

As stated in Section 2, the workshop process was designed to collect ocean exploration needs and associated approaches for satisfying those needs from each of the participating regions. During the conduct of the workshops, discussion among participants often migrated to issues related to the OE program that were not representative of specific ocean exploration needs or approaches. Several issues common to multiple workshops are included in this section to ensure their inclusion within this report and to recognize the contribution of these discussions to the value of the workshops.

- *Data Management*. The issue of managing ocean exploration data was raised at each of the eight regional workshops. Participants were generally concerned about the lack of standardized data management policies and procedures throughout the oceanographic community. Recognizing the need for managing exploration data and its value to a broad community of public and private stakeholders, participants were

equally concerned about the availability of resources within the government to support a viable OE data management process. Several attendees noted that principal investigators tend to be apprehensive over timely release of data to the public due to the potential for competing interests—particularly well-funded commercial entities—to exploit these data at their expense. There was a common recognition of the importance for OE to develop standardized, flexible data management policies and procedures and integrate them into the OE program.

- *Existing Information and Data Mining*. Workshop participants recognized the likely existence of many oceanographic databases that could expand the scientific knowledge baseline if they were accessible. Many databases are privately owned by industry due to their commercial and competitive value. An example is in the Gulf of Mexico region, where industry databases of high-resolution bathymetry and sub-bottom profiles are known to exist. Without access to these data, explorers in this region working in the public interest have been obliged to recreate these data at considerable expense. The workshop attendees also noted the broader issue of the need for data mining services that could access as many existing public and private databases as possible. There was general agreement that these services were beyond the scope of the OE program but should be addressed by entities charges with the responsibility for environmental data and information services. Participants encouraged the current OE practice of working with a large number of collaborators in order to create strategic partnerships that could enable greater access to other data sources.

- *Definition of Ocean Exploration*. Despite the guidance contained in the *Frontier* Report and the OE Announcements of Opportunity, participants held varying definitions of ocean exploration and the scope of activities that they thought should be sponsored by the OE program. Attendees sought to clearly separate exploration from basic research, and coastal zone exploration from ocean exploration. With guidance provided by OE leadership at each of the workshops, the participants generally recognized that concise and complete definitions were difficult to achieve, and that the potential reach of exploration activities is defined in part by the level of resources available to the OE program. It was generally agreed that continued exposure of the OE program and its activities would lead to a greater understanding of the scope of the program among the various exploration stakeholders.

- *Outreach.* Many workshop participants sought greater time during the process for OE program outreach. The general consensus among workshop participants was that outreach would be critical to the future success of the OE program. Attendees were pleased to learn that OE had adopted an internal policy of allocating 10 percent of its annual budget for education and outreach functions. Many participants felt that current outreach efforts should be expanded, and that the general public residing in areas removed from the oceans—where the connections between the oceans and the daily impact on their livelihood are not as apparent—should be a specific outreach target. Several participants recommended that OE host a national conference with a focus on ocean exploration outreach to the public.

- *Maritime Heritage.* At each of the eight regional workshops, attendees representing the marine archeology community expressed support for the OE program emphasis on finding and preserving maritime heritage resources and sought additional methods for protecting submerged historical sites from exploitation. Submerged historical findings are a great way to stimulate public interest, but once information on these findings is made public these sites often suffer from uncontrolled and unregulated access. It was suggested that the OE program could participate in sponsoring an educational campaign that would focus on maritime preservation issues such as responsible shipwreck diving by recreational and commercial divers.
- *Local Knowledge.* In the Alaska and West Coast regional workshops, the use of traditional, local knowledge as a component of ocean exploration was emphasized as an idea that warrants further examination. Participants at these workshops noted that indigenous populations such as the Inuit and Native Americans might have considerable oceanographic knowledge that has been overlooked for many years. It was suggested that OE examine practical ways to make use of these resources through creative collaboration and outreach efforts.
- *Taxonomic Expertise.* In several workshops, the need for resources with taxonomic expertise was identified as a critical issue. Participants generally felt that there is a decreasing pool of these experts within the oceanographic community due to the inability of individuals to center their career aspirations in such a narrowly focused field. Many expressed the concern that the taxonomic baseline was becoming diluted and that marine organisms are increasingly being assigned inaccurate taxonomy, making it difficult to characterize new discoveries. At one workshop, the attendees decided that this issue was important enough that the government should consider establishing a professional series for taxonomic specialists to ensure an appropriate emphasis on the need.